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FINAL REPORT
SEPTEMBER 1992

REPORT NO. 92-19

KUWAIT STINGER MISSILE TEMPERATURE MONITORING PROGRAM, SUMMER 1992

Prepared for:
Commander
U.S. Army Missile Command
ATTN: SFAE-MSL-ATA-SE
Redstone Arsenal, AL 35898-5070

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U.S. ARMY DEFENSE AMMUNITION CENTER AND SCHOOL

VALIDATION ENGINEERING DIVISION
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19. ABSTRACT (Continue on reverse if necessary and identify by block number)

The U.S. Army Defense Ammunition Center and School (USADACS), Validation Engineering Division (SMCAC-DEV), was tasked by U.S. Army Missile Command (MICOM) to monitor STINGER missile temperatures in Kuwait during the summer of 1992. This test was initiated after environmental simulations indicated STINGER missiles could exceed 200 degrees Fahrenheit while stored in desert-like conditions. To resolve this dilemma and replacement of costly missile components onsite, tests were conducted at an ammunition supply point (ASP) located in Kuwait. The following report contains peak daily temperatures at specific locations on the missiles from July - September 1992. Maximum temperature during testing reached 168 degrees Fahrenheit on the missile launch tube, with no temperatures approaching 200 degrees Fahrenheit.

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U.S. ARMY DEFENSE AMMUNITION CENTER AND SCHOOL
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REPORT NO. 92-19

KUWAIT STINGER MISSILE TEMPERATURE MONITORING PROGRAM, SUMMER 1992

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PART 1

INTRODUCTION

A. BACKGROUND. The U.S. Army Defense Ammunition Center and School (USADACS), Validation Engineering Division (SMCAC-DEV), was tasked by U.S. Army Missile Command (MICOM) to monitor STINGER missile temperatures in Kuwait during the summer of 1992. This test was initiated after environmental simulations indicated missiles could exceed 200 degrees Fahrenheit while stored in desert-like conditions during Operation Desert Storm. To resolve this dilemma and replacement of costly missile components onsite, tests were conducted at an ammunition supply point (ASP) located in Kuwait. The following report contains peak daily temperatures at specific locations on the missiles from July - September 1992.

B. AUTHORITY. This test was conducted IAW mission responsibilities delegated by the U.S. Army Armament, Munitions and Chemical Command (AMCCOM), Rock Island, IL.

C. OBJECTIVE. The objective of this test was to determine maximum temperatures STINGER missiles experienced while stored in desert-like conditions in Kuwait. Based on test results, decisions could be made as to the replacement of costly missile components as well as recalibration of environmental chambers for more accurate temperature simulations of missiles.

D. CONCLUSION. Based on 62 days of testing in Kuwait, it is very unlikely that STINGER missiles will ever experience temperatures approaching 200 degrees Fahrenheit while stored in desert-like conditions. The highest recorded temperature during this test was 168.3 degrees Fahrenheit on the missile launch tube laying unprotected in the sand. Missile temperatures experienced in Kuwait simulate temperatures experienced in Saudi Arabia (SA) during

Operation Desert Storm, with the TOW missile reaching a maximum temperature of 161 degrees Fahrenheit.

PART 2

JULY - SEPTEMBER 1992

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PART 3

TEST SETUP

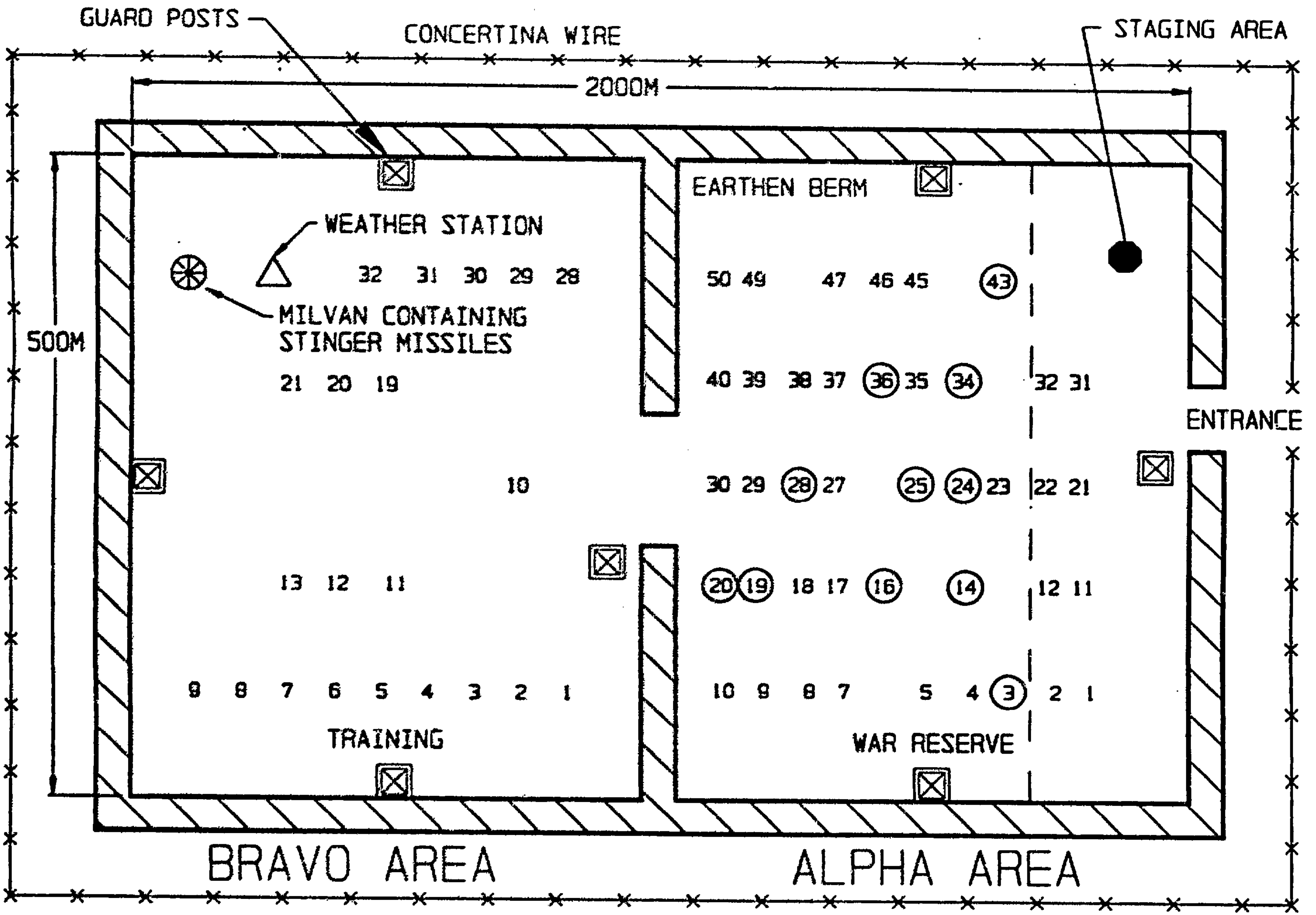
The tests were conducted at the ammunition supply point (ASP) located in Kuwait, approximately 30 miles from the Iraqi border. This ASP contained Alpha area (war reserves) and Bravo area (training rounds), with all tests being conducted in Bravo area. A Climatronics weather station was installed to monitor environmental conditions which included wind speed, solar radiation, temperature and humidity. Measurements were taken every 15 seconds for a period of 15 minutes with the peak readings recorded. Additionally, the weather station contained 64 channels to monitor specific points on the STINGER missiles. These readings were also taken every 15 seconds with peaks readings recorded every 15 minutes. The following tests were conducted:

a. STINGER missile in a shipping container inside a Military Van (MILVAN),

b. Unprotected STINGER missile laying in the sand, exposed directly to solar radiation to create a "worst case" scenario.

c. STINGER missile in shipping container exposed directly to solar radiation.

Data during these tests were downloaded weekly and provided to MICOM for data analysis. Drawing 1 provides the general ASP layout with drawings 2,3, and 4 showing specific thermocouple locations on the missiles.



AMMUNITION STORAGE SITE IN KUWAIT

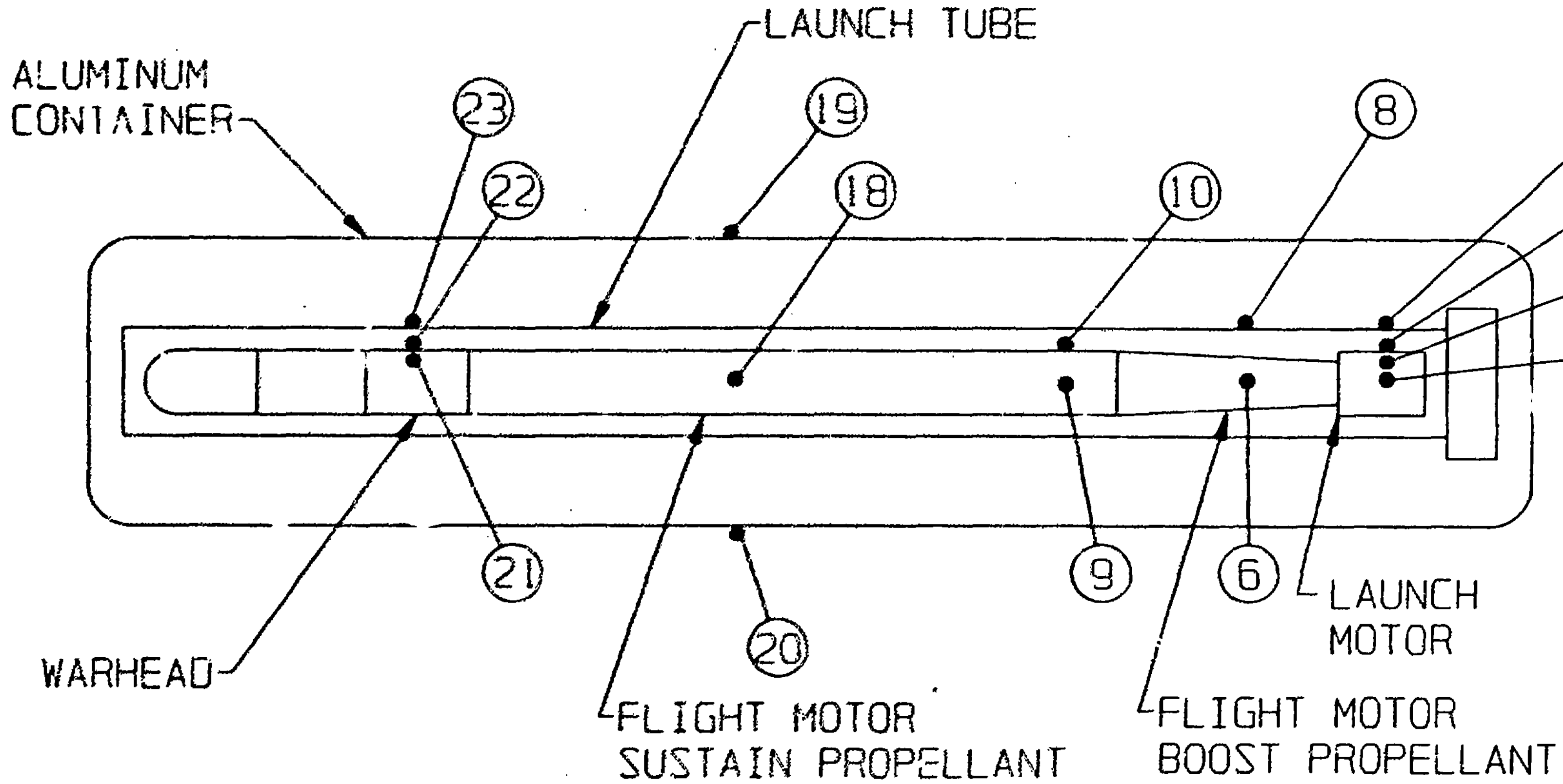
○ = MIVANS THAT ARE INSTRUMENTED

NOTE: MAXIMUM OF 26 MILVANS FOR EACH PAD

Thermocouple Locations
STINGER Missile In MILVAN

Thermocouple	Location
1	0.01-inch inside the missile at the 1 o'clock angular position attached to the outside row.
2	0.01-inch inside the missile at the 12 o'clock angular position attached to the second row.
3	Outside diameter of launch motor directly above thermocouple number 1.
4	Outside diameter of launch tube directly above thermocouple number 3.
6	Booster propellant and insulation interface.
8	Outside diameter of launch tube.
9	Sustain propellant and insulation interface.
10	Outside diameter of flight motor case over thermocouple number 9.
18	Air temperature inside to missile shipping container.
19	Temperature of outside top of missile shipping container.
20	Temperature of outside bottom of missile shipping container.
21	0.02-inch from the warhead case inside diameter located in wax.
22	Outside diameter of warhead case directly above thermocouple number 21.
23	Outside diameter of launch tube directly above thermocouple number 22.

THERMAL COUPLE LOCATION ON STINGER MISSILE
INSIDE THE MILVAN



NOTE

1. ● = THERMALCOUPLE LOCATION

FOR INFORMATION ONLY

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STINGER MISSILE MOTOR TEMPERATURE EVALUATION IN KUWAIT	92-019-0-S00030
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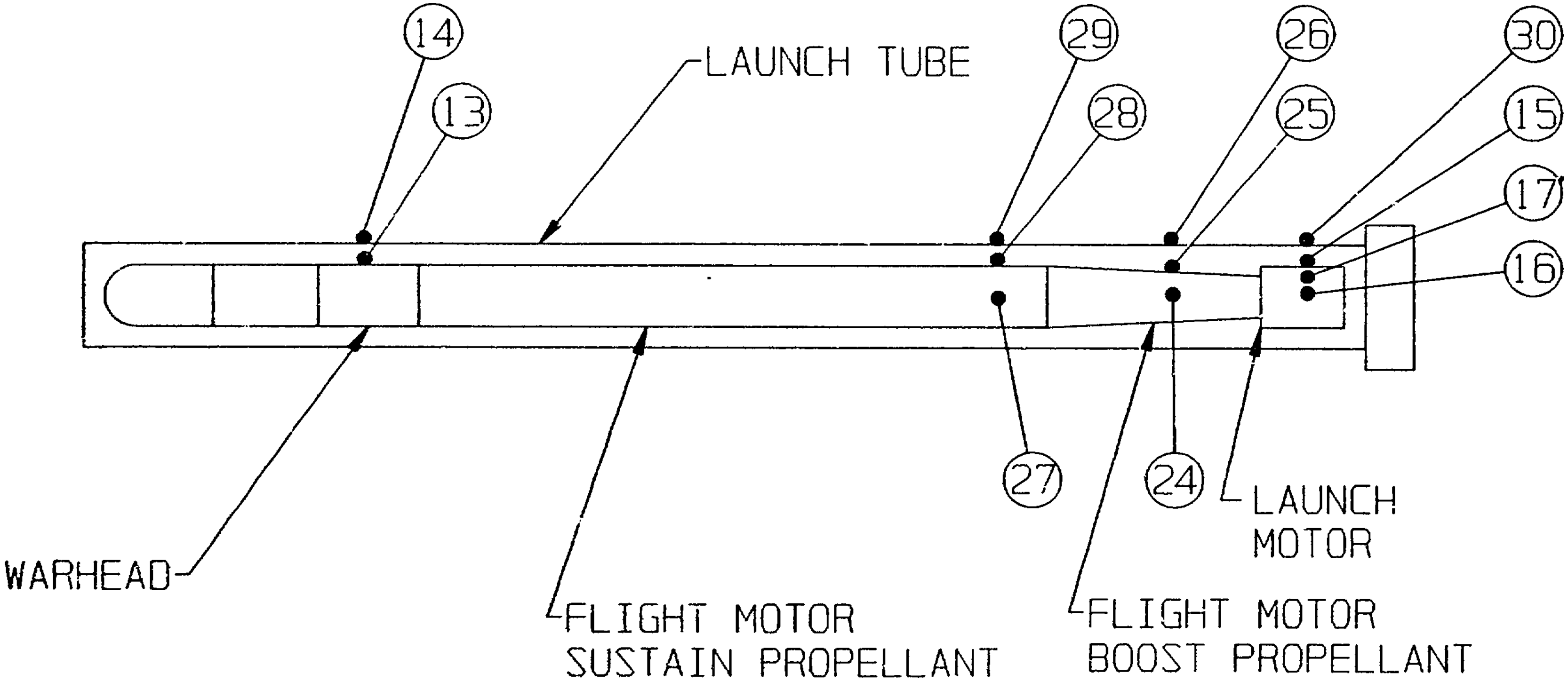
Thermocouple Locations
STINGER Missiles Outside the MILVAN

Thermocouple	Location
13	Outside diameter of warhead.
14	Outside diameter of launch tube directly above thermocouple number 13.
15	Outside diameter of launch motor directly above thermocouple number 16.
16	0.01-inch inside the missile at the 1 o'clock position attached to the outside row.
17	0.01-inch inside the missile at the 12 o'clock position attached to the second row.
24	Booster propellant and insulation interface.
25	Outside diameter of flight motor case directly above thermocouple number 24.
26	Outside diameter of launch tube.
27	Sustain propellant and insulation interface.
28	Outside diameter of flight motor case over thermocouple number 27.
29	Outside diameter of launch tube above thermocouple number 28.
30	Outside diameter of launch tube directly above thermocouple number 15.

THERMAL COUPLE LOCATION ON STINGER MISSILE
OUTSIDE THE MILVAN



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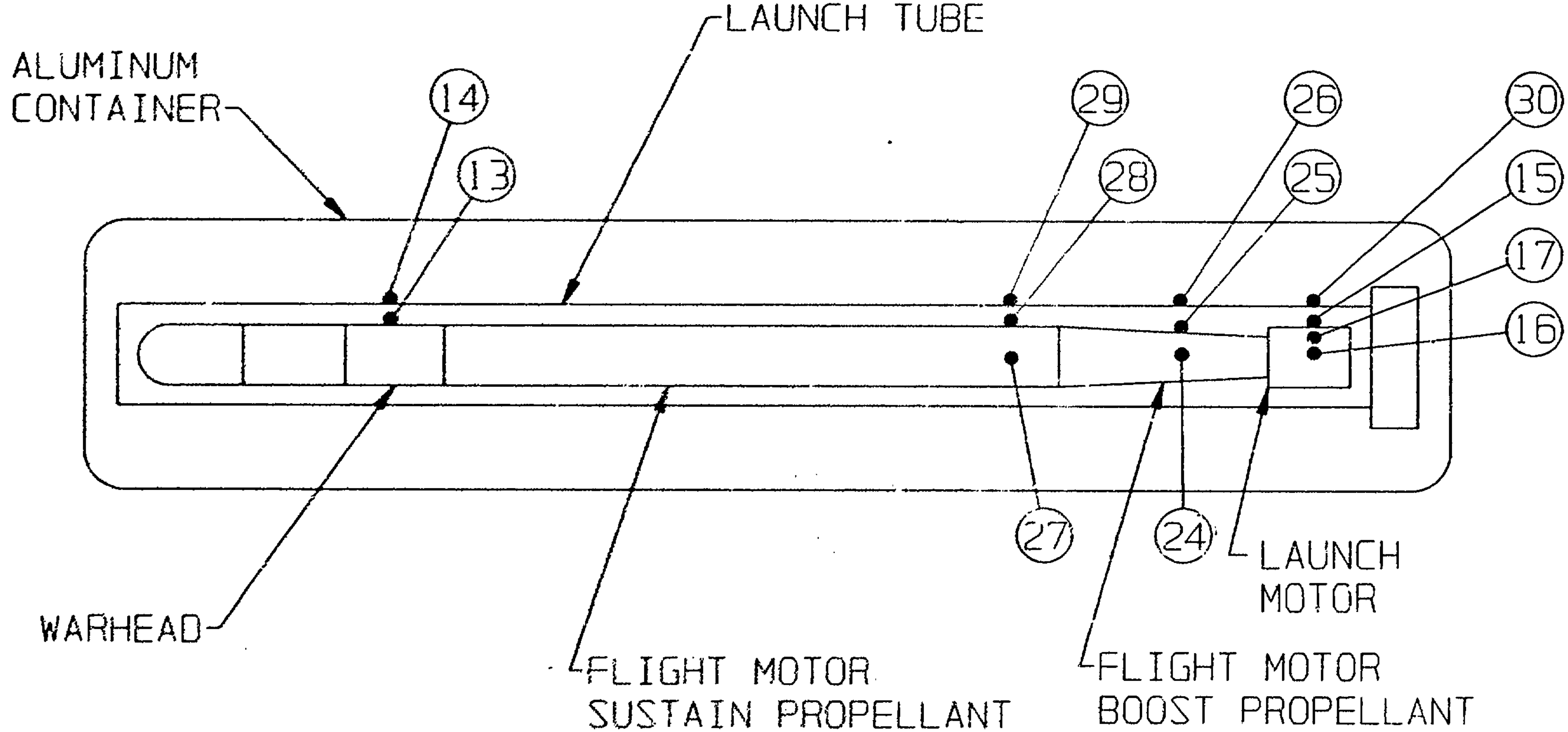
TITLE STINGER MISSILE MOTOR TEMPERATURE EVALUATION IN KUWAIT	DWG NO 92-019-0-S00033
	VALIDATION ENGINEERING DIVISION — SHEET 1 OF 1

THERMAL COUPLE LOCATION ON STINGER MISSILE
IN CONTAINER OUTSIDE THE MILVAN



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TITLE	DWG NO
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PART 4

TEST RESULTS

A. KUWAIT ENVIRONMENTAL TEST CONDITIONS. Environmental conditions in which the STINGER missiles were tested were severe. Some of the variables that effect missile temperatures include ambient temperature, humidity, solar radiation,wind speed, wind direction, haze, cloud cover, sand storms, etc., to name a few. All variables interact effecting the ultimate temperature of the missile and components. Due to the complexity of these interactions, duplication under laboratory conditions is extremely difficult, if not impossible. With that in mind, the conditions in which the missiles were tested were as follows. The average daily high peak temperature reached 111.2 degrees Fahrenheit with the highest temperature being 119.9 degrees Fahrenheit on Julian date 229. The average daily high solar radiation was 231.1 BTUs/hour/foot^2, with the highest reading being 272.3 BTUs/hour/foot^2 on Julian date 202. Due to the location of the solar radiation gauge, readings reported above may not be maximum solar radiation readings for Kuwait. Average daily high humidity was 45.2 percent with the highest reading being 92.0 percent on Julian date 248. Average daily high wind speed was 72.1 mph with the highest reading being 134.6 mph on Julian date 205. Table 1 shows the 10 hottest days during testing (see part 6 for graphs depicting peak temperatures and part 7 for daily high environmental conditions).

Table 1

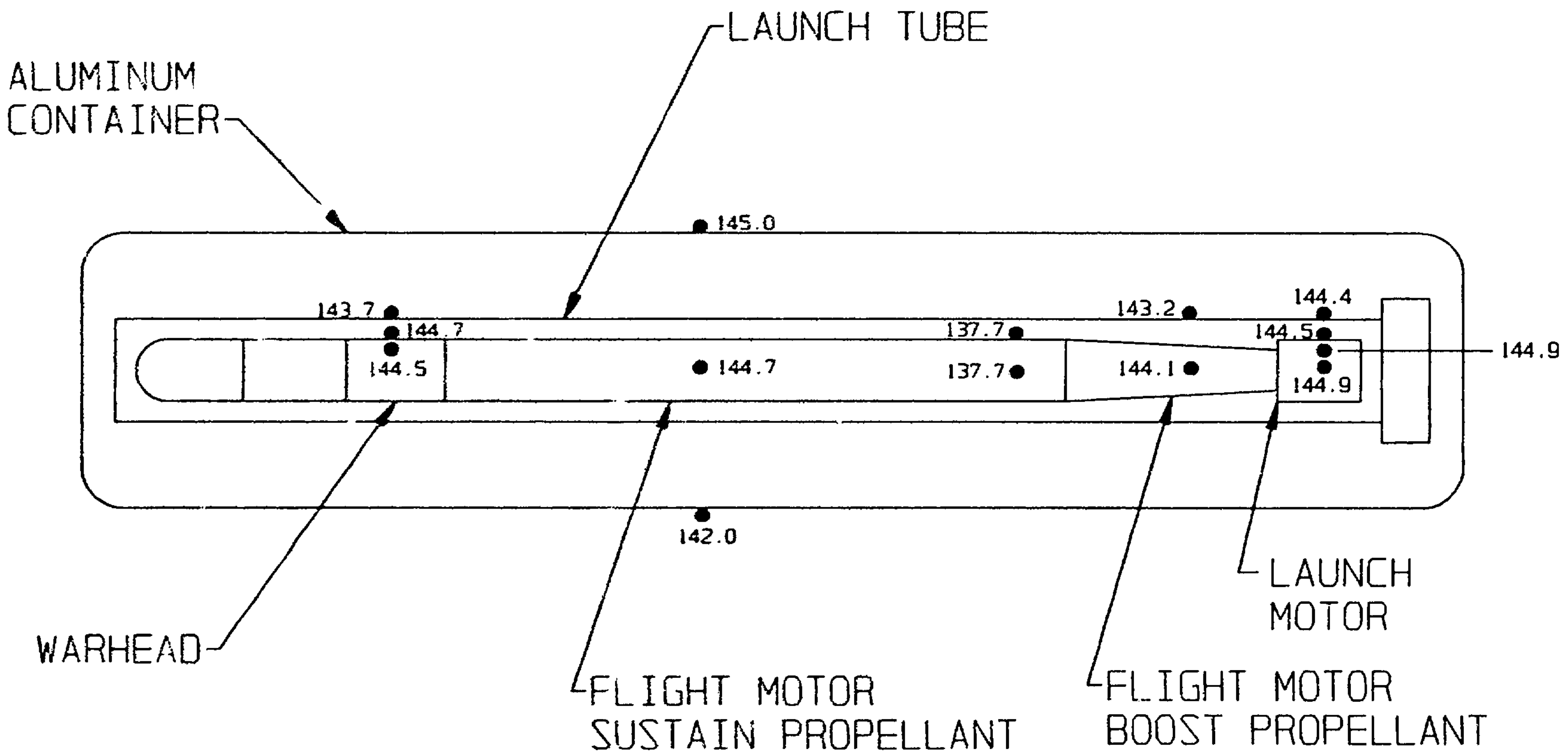
Kuwait Environmental Conditions, Peak Temperatures, Ten Hottest Days

Julian Date	Wind Speed (MPH)	Ambient Temperature (Fahrenheit)	Ambient Humidity (Percent)	Solar Radiation (BTU/hr/ft^2)
203	67.54	117.30	33.20	258.83
221	56.52	115.70	55.86	248.21
222	48.74	116.90	45.19	241.35
223	58.19	116.80	59.09	251.53
228	59.66	116.70	35.44	253.30
229	37.61	119.90	41.19	239.58
230	94.80	117.00	34.61	249.76
235	56.13	115.60	41.78	226.75

Julian Date	Wind Speed (MPH)	Ambient Temperature (Fahrenheit)	Ambient Humidity (Percent)	Solar Radiation ($BTU/hr/ft^2$)
236	61.40	115.20	50.68	229.18
237	92.50	116.20	42.43	233.17

B. TEST RESULTS OF STINGER MISSILE IN MILVAN. A STINGER missile with shipping container was instrumented with 14 thermocouples with readings recorded every 15 minutes. At the completion of testing, data were downloaded and analyzed for maximum temperature and average daily high temperature and reported on drawings 5 and 6. As can be noted from drawing 5, the maximum temperature experienced by the STINGER missile while in the MILVAN was 145 degrees Fahrenheit on the top surface of the shipping container. The maximum temperature of the warhead was 144.7 degrees Fahrenheit, the flight motor sustain propellant 144.7 degrees Fahrenheit, flight motor booster propellant 144.1 degrees Fahrenheit, and the launch motor at 144.9 degrees Fahrenheit. All maximum temperatures were within 141.35 +/- 3.65 degrees Fahrenheit, indicating long periods of uniform high temperatures. These long periods of high temperatures allow for uniform heat distribution throughout the missile components. Of interest during this test was the region between the flight motor sustain propellant and flight motor booster propellant, with a maximum temperature of only 137.7 degrees Fahrenheit, or approximately 7 degrees cooler than adjacent areas on the missile. Temperature data of more importance is the average daily high temperature of missile components while stored in the MILVAN. These readings give long-term temperature conditions in which the missiles were stored. The values reported in drawing 6 summarize average daily high temperatures over the life of the test. As can be noted from drawing 6, the shipping container had the hottest daily high temperature at 131.66 degrees Fahrenheit with all missile components experiencing average daily high temperatures in the range of 127.2 +/- 4.1 degrees Fahrenheit. Again, as noted in drawing 5, the coolest part of the missile system was the region between the sustain propellant and the booster propellant at 8 degrees Fahrenheit below adjacent areas (see part 6 for graphs depicting maximum daily high temperatures and part 7 for temperature data).

THERMAL COUPLE LOCATION ON STINGER MISSILE INSIDE THE MILVAN MAXIMUM TEMPERATURE



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TITLE STINGER MISSILE MOTOR TEMPERATURE EVALUATION IN KUWAIT	DWG NO 92-019-0-S00031	
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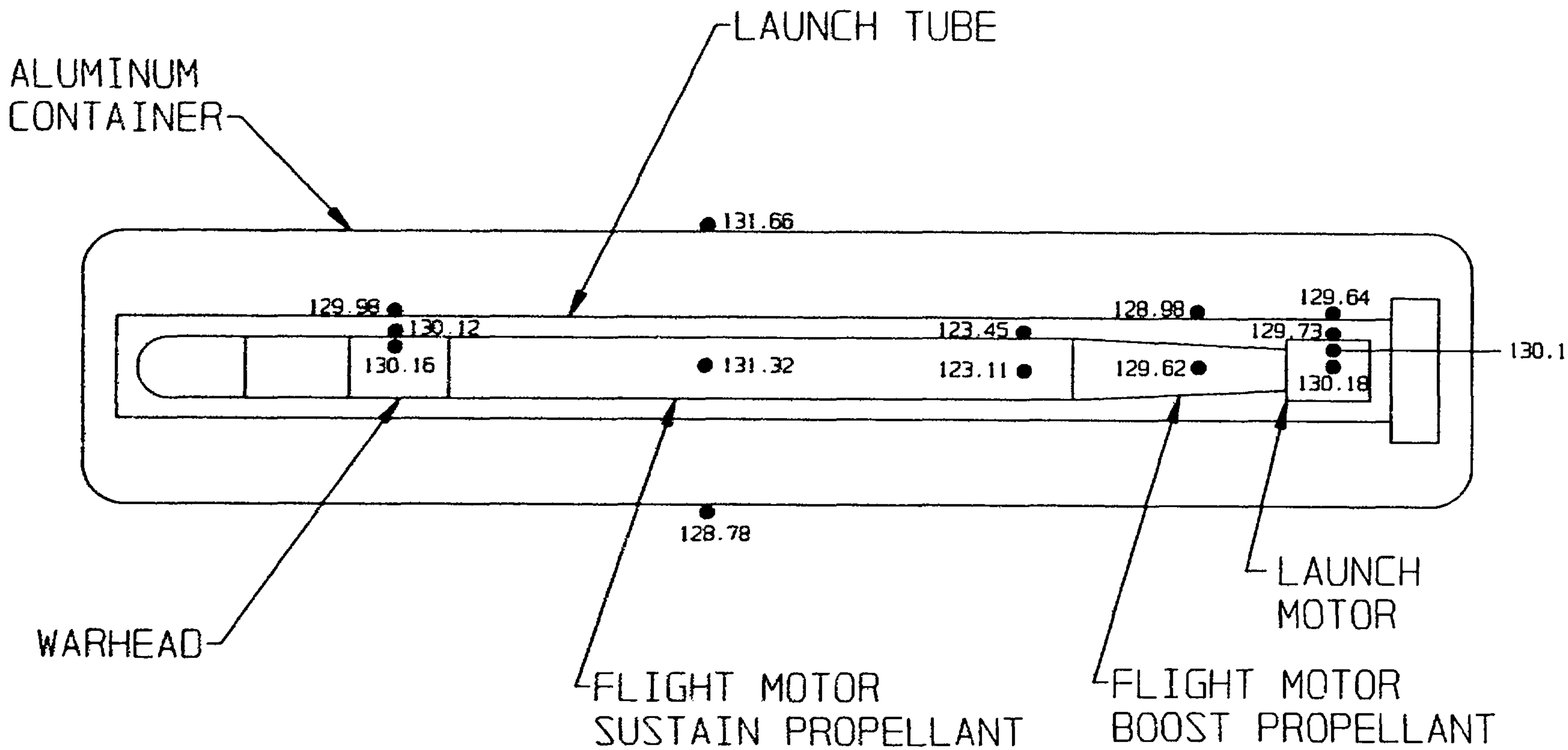
THERMAL COUPLE LOCATION ON STINGER MISSILE INSIDE THE MILVAN DAILY AVERAGE HIGH TEMPERATURE



NOTE:

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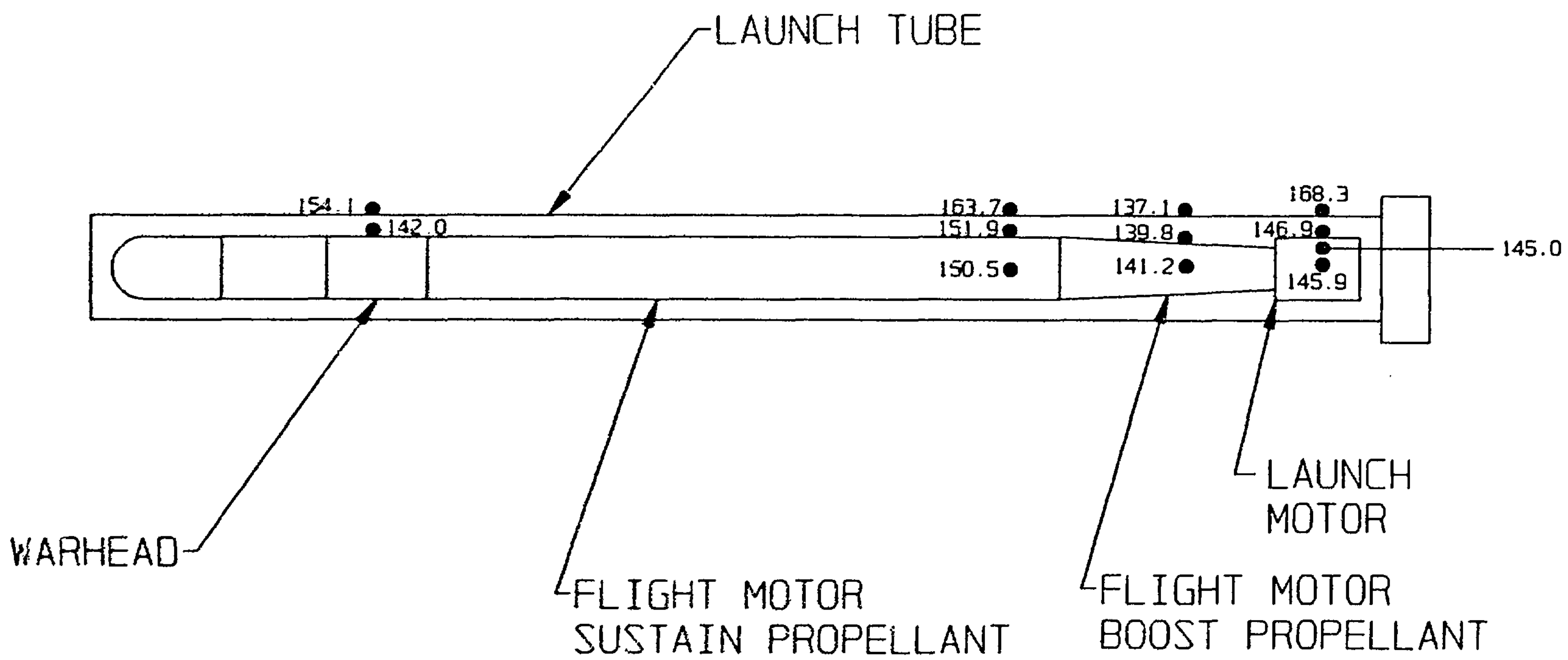
C. TEST RESULTS OF STINGER MISSILE LAYING IN THE SAND.

1. To determine a "worst case" scenario for the STINGER missile, one missile was instrumented and exposed directly to solar radiation while unprotected (drawing 7 depicts maximum temperatures experienced during this test). As noted, the launch tube experienced the highest temperature at 168.3 degrees Fahrenheit. Maximum internal temperatures ranged from 139.8 degrees Fahrenheit to 151.9 degrees Fahrenheit. The hottest internal component was the aft section of the flight motor sustain propellant at 151.9 degrees Fahrenheit and the coolest was the flight motor booster propellant. Of interest during this test is a comparison of maximum internal temperatures experienced by the STINGER missile while stored inside and out of the MILVAN. By comparing drawings 5 and 7, it was noted that maximum internal temperatures (inside the launch tube) of both missiles were very similar, 137.7 degrees Fahrenheit to 144.9 degrees Fahrenheit, inside the MILVAN versus 139.8 degrees Fahrenheit to 151.9 degrees Fahrenheit outside the MILVAN. Therefore, storage outside that is unprotected will cause a temperature increase of only 2 degrees Fahrenheit to 7 degrees Fahrenheit on internal missile components.

2. Drawing 8 depicts the average daily high temperatures of the STINGER missile while exposed directly to solar radiation. As shown, the hottest section was the midsection of the launch tube at 144.9 degrees Fahrenheit. Internal temperatures (inside the launch tube) for the STINGER missile ranged from 124.8 degrees Fahrenheit to 136.7 degrees Fahrenheit. Again, comparing temperature data both inside and outside of the MILVAN (drawings 6 and 8), internal components were only 1.6 degrees Fahrenheit to 6.5 degrees Fahrenheit hotter outside of the MILVAN.

3. A comparison of temperature data for the MILVAN and direct exposure to sunlight was somewhat surprising. It suggests that unprotected MILVANs provide very little protection from heat damage if the heating cycles are long enough to provide complete temperature soaking of missile components. As a comparison, TOW missiles were instrumented at the same ASP in a MILVAN containing a tin roof 1 foot above the MILVAN for solar shading. The maximum external temperature for the TOW missile was 132.2 degrees Fahrenheit versus 145.0 degrees Fahrenheit for the STINGER missile inside the unprotected MILVAN. This 13-degree temperature differential seems to demonstrate the advantage of solar shading (see parts 6 and 7 for graphs and temperature data).

THERMAL COUPLE LOCATION ON STINGER MISSILE
OUTSIDE THE MILVAN MAXIMUM TEMPERATURE



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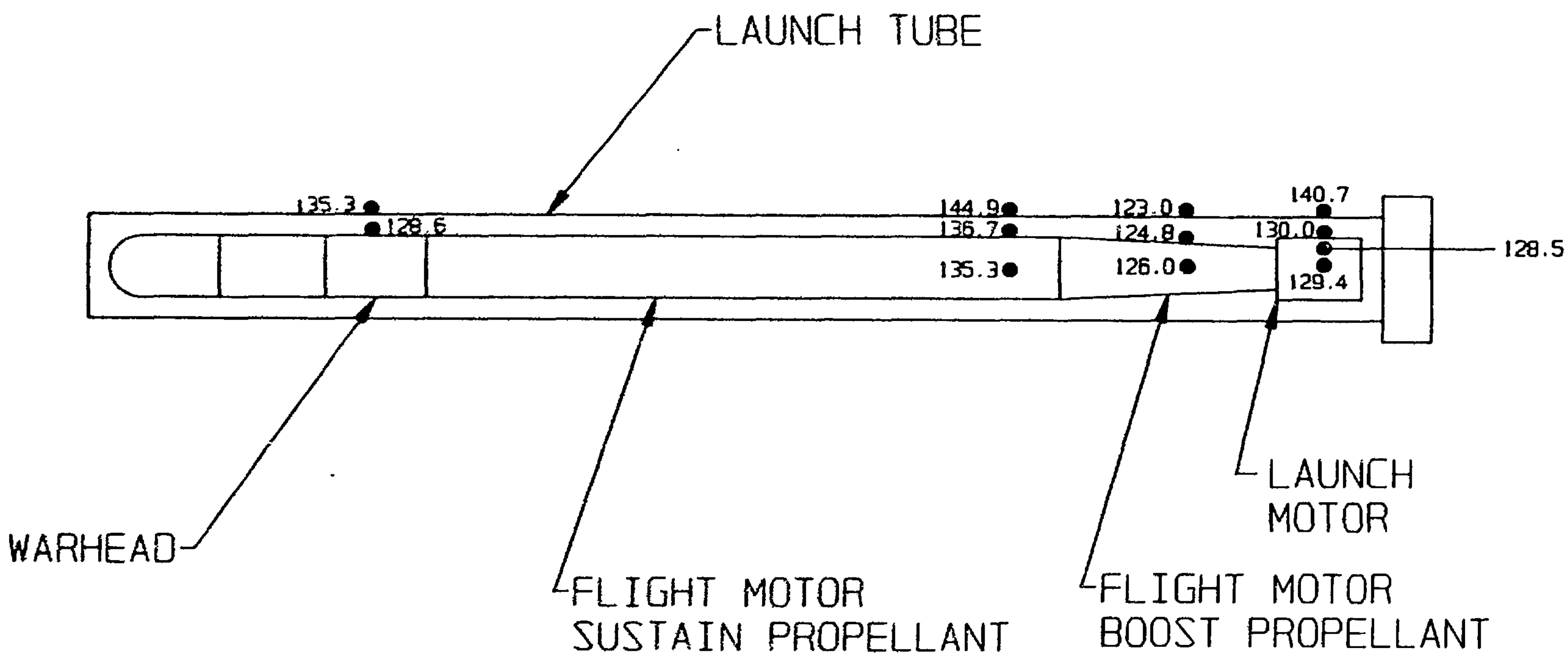
THERMAL COUPLE LOCATION ON STINGER MISSILE
OUTSIDE THE MILVAN DAILY AVERAGE HIGH TEMPERATURE



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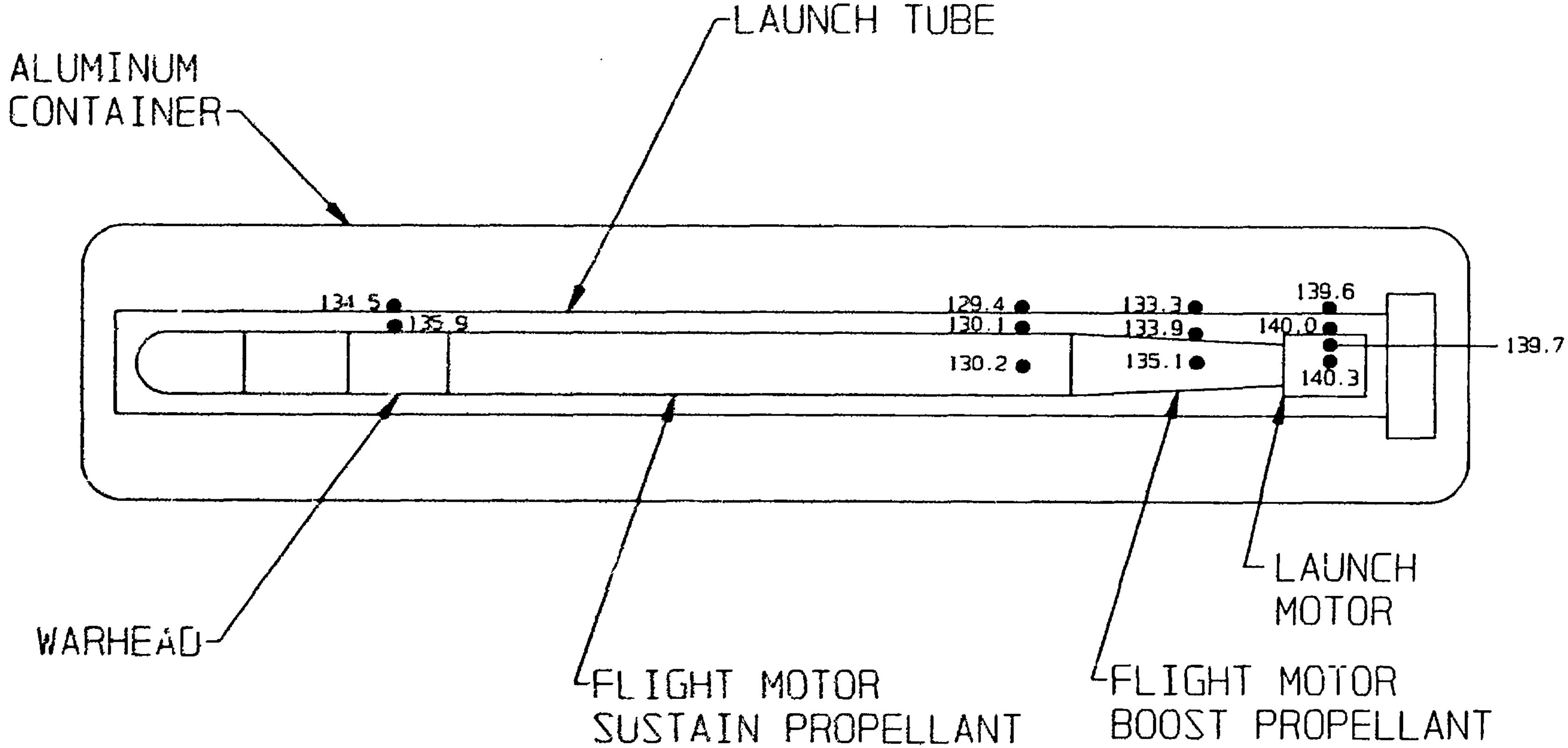
TITLE	DWG NO
STINGER MISSILE MOTOR TEMPERATURE EVALUATION IN KUWAIT	92-019-0-S00035
	VALIDATION ENGINEERING DIVISION — SHEET 1 OF 1

D. TEST RESULTS OF STINGER MISSILE IN SHIPPING CONTAINER STORED OUTSIDE THE MILVAN.

1. The maximum temperature for the STINGER missile in a shipping container while stored outside the MILVAN was 140.3 degrees Fahrenheit on the launch motor. The coolest component was the aft section of the flight motor sustain propellant at 129.4 degrees Fahrenheit (see drawing 9). As previously reported, the aft section of the flight motor sustain propellant was also the coolest section while stored in the MILVAN, and it was thought to be due to the shipping container design and packing material.

2. The average daily high temperature for this test was 121.7 degrees Fahrenheit to 129.9 degrees Fahrenheit (see drawing 10) with the launch motor again being the hottest and sustain propellant the coolest. This 8-degree temperature differential again indicates long periods of high temperatures with adequate soak time for uniform temperature distribution. This test began during late summer of 1992; as such, temperatures are somewhat lower than previous tests.

THERMAL COUPLE LOCATION ON STINGER MISSILE IN CONTAINER OUTSIDE THE MILVAN MAXIMUM TEMPERATURE



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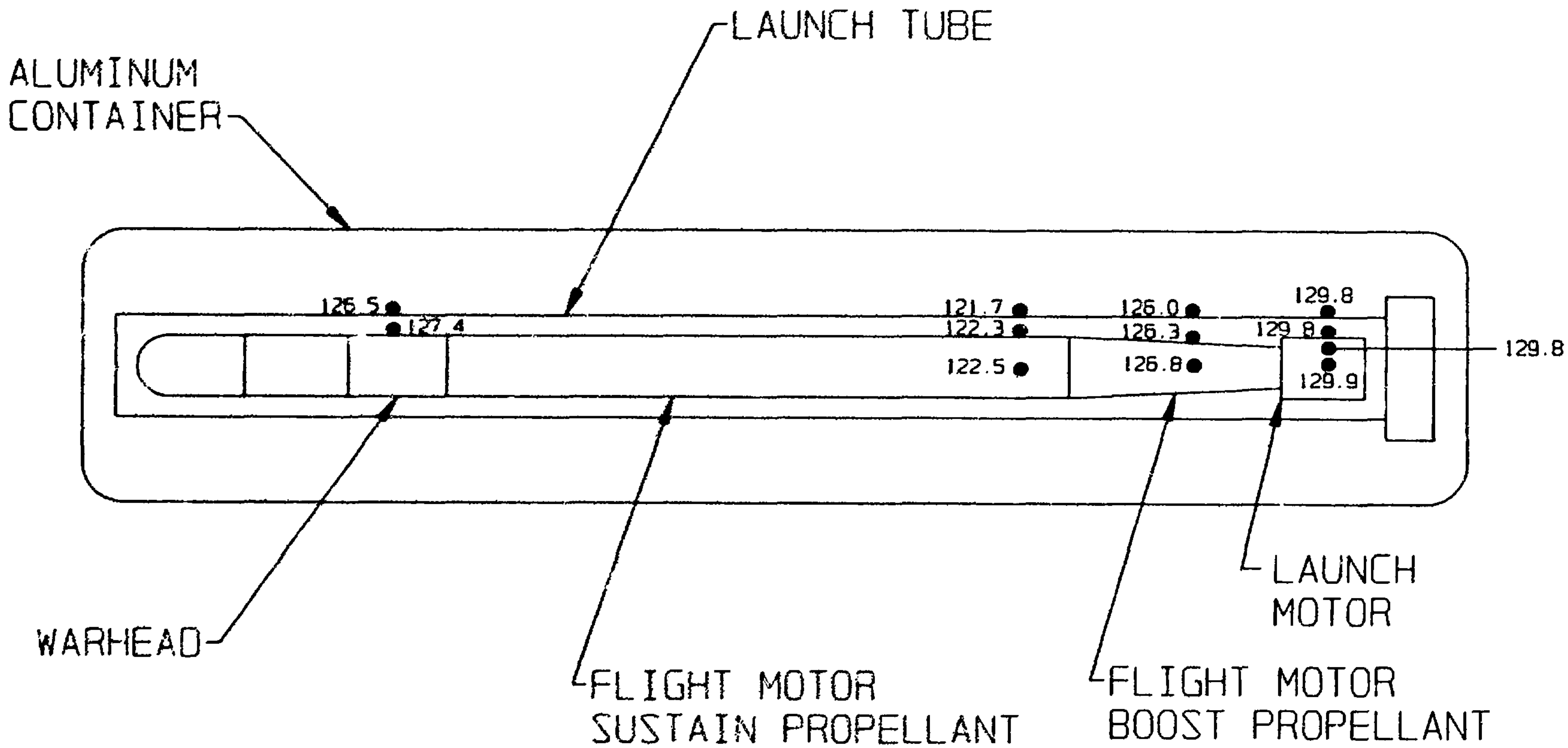
THERMAL COUPLE LOCATION ON STINGER MISSILE IN CONTAINER OUTSIDE THE MILVAN DAILY AVERAGE HIGH TEMPERATURE



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PART 5

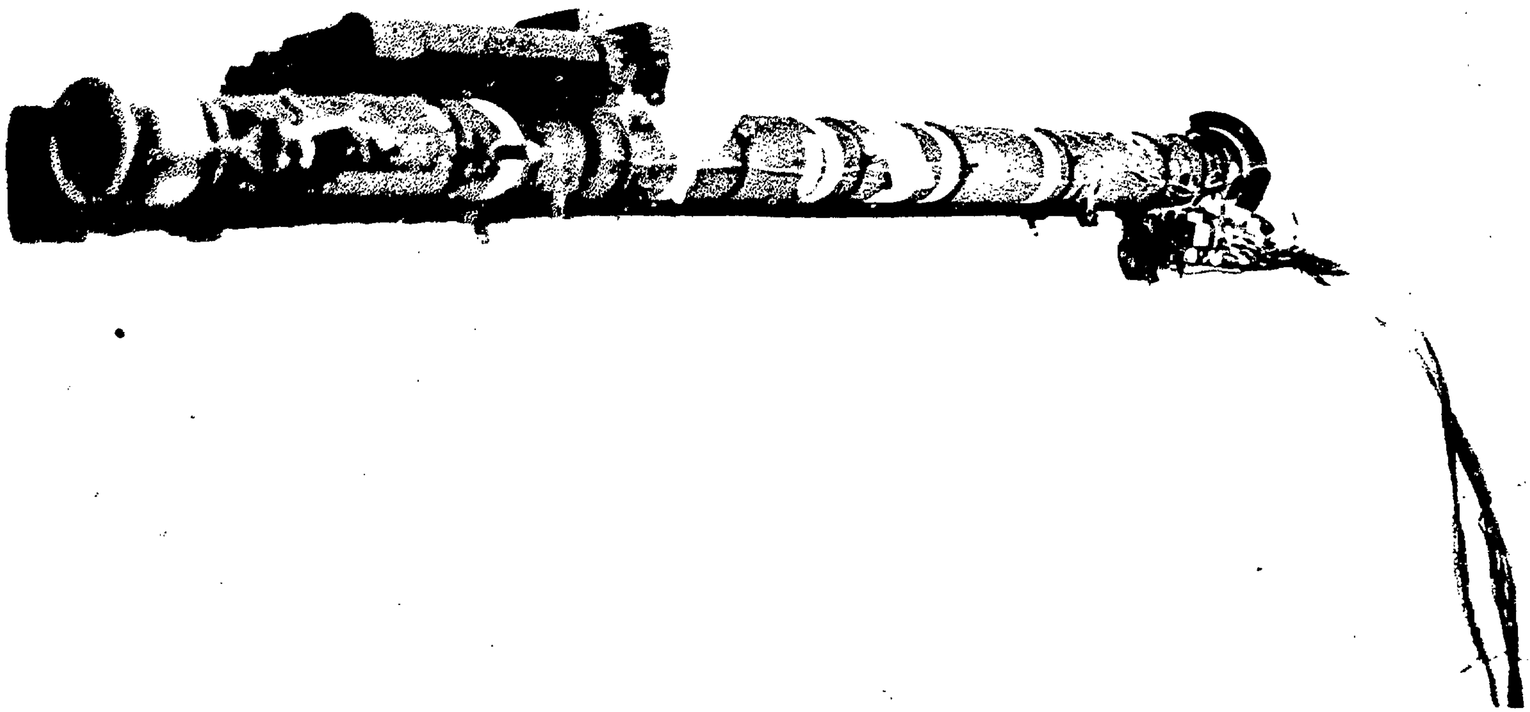
PHOTOGRAPHS

	U.S. ARMY DEFENSE AMMUNITION CENTER AND SCHOOL - SAVANNA, IL	

Photo No. AO317-SCN92-384-3216. This photo shows the general test setup for the STINGER missile. Note: the STINGER missile container on the right side of the photo as well as the bare STINGER round in the center photo next to the MILVAN.

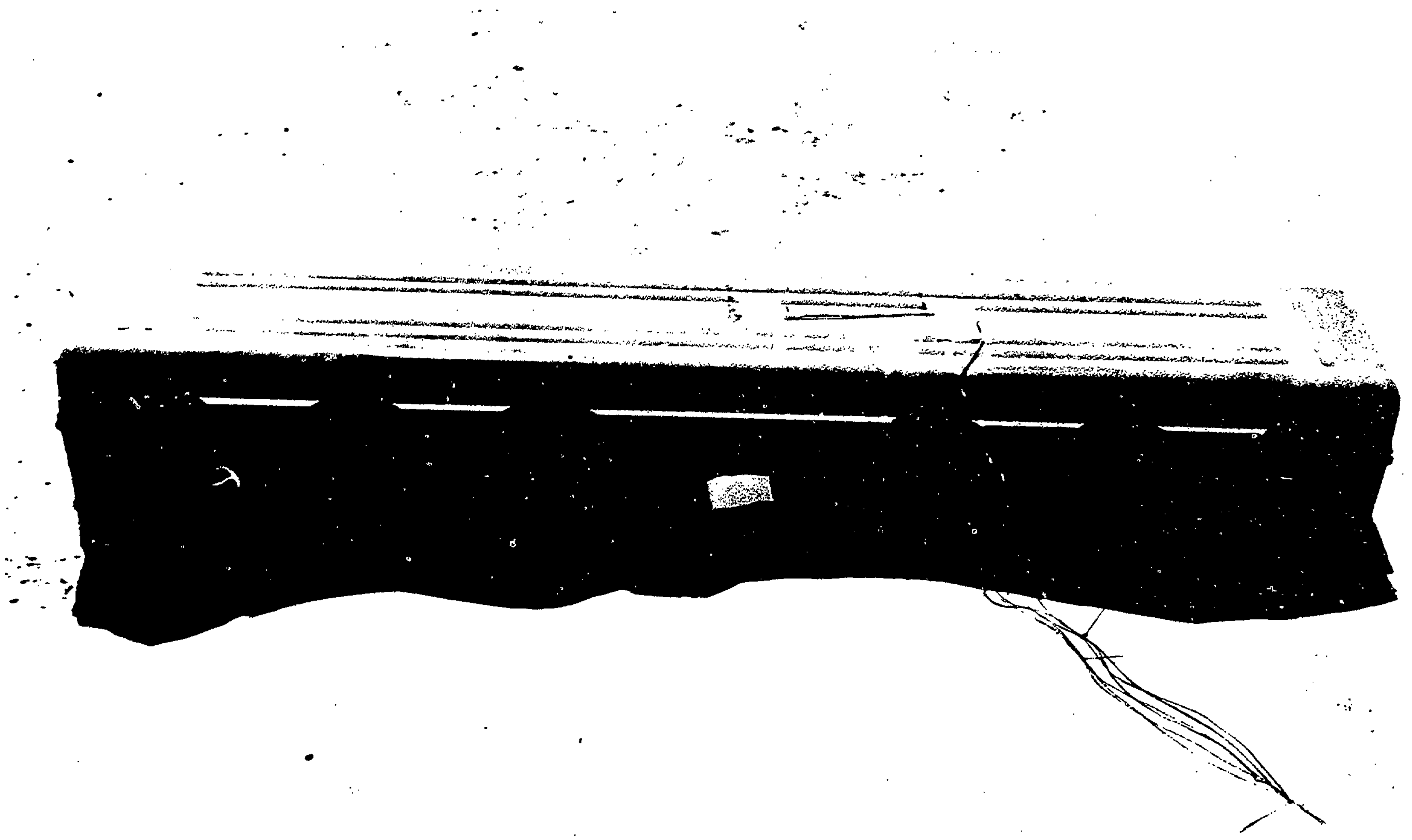
	U.S. ARMY DEFENSE AMMUNITION CENTER AND SCHOOL - SAVANNA, IL	

Photo No. AO317-SCN92-300-3339. This photo shows a closeup view of the STINGER missile within the MILVAN, located approximately 1 foot from the MILVAN roof.



	U.S. ARMY DEFENSE AMMUNITION CENTER AND SCHOOL - SAVANNA, IL	

Photo No. AO317-SCN92-300-3337. This photo shows a closeup view of the STINGER missile laying bare in the sand.



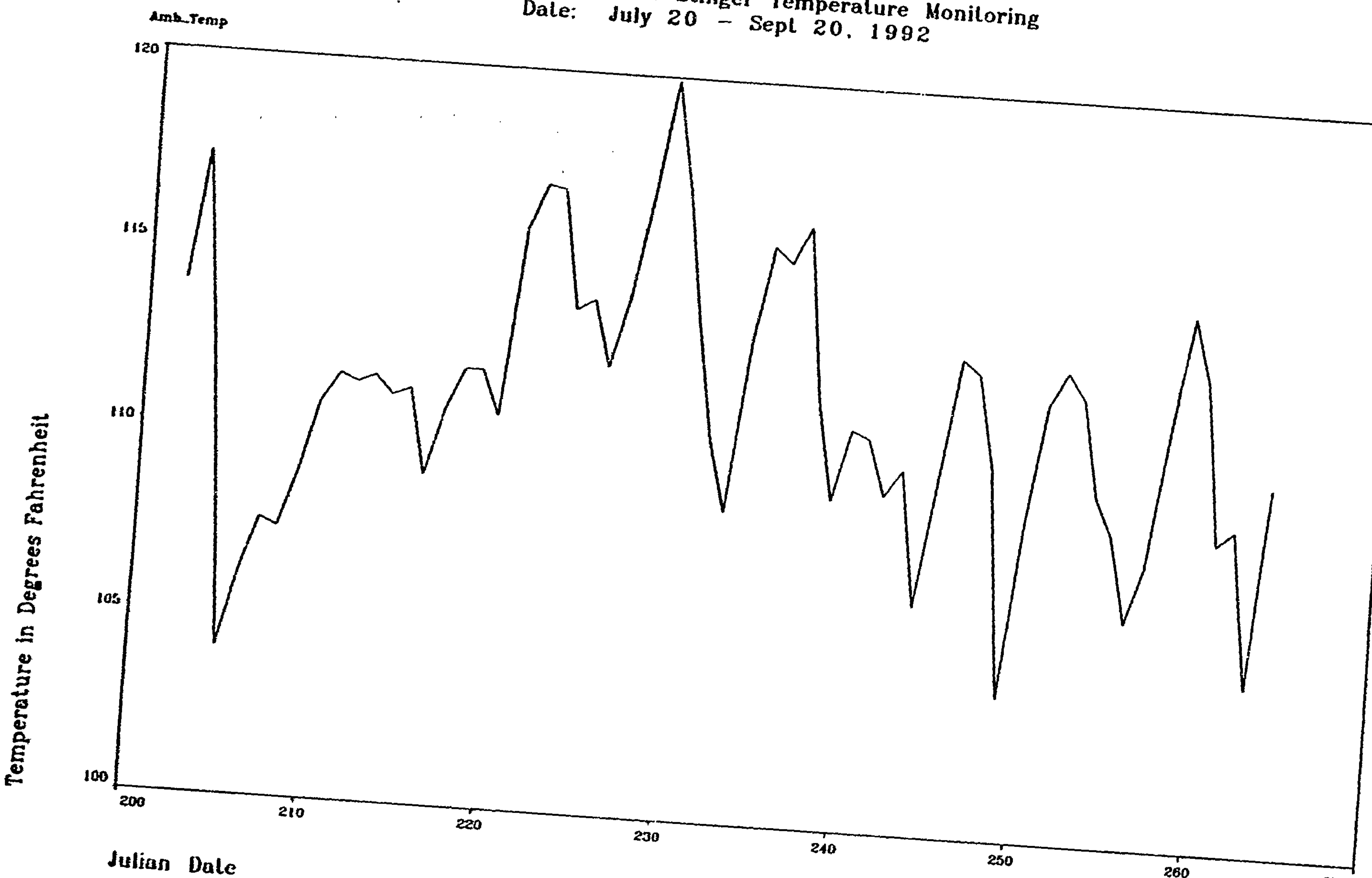
U.S. ARMY DEFENSE AMMUNITION CENTER AND SCHOOL - SAVANNA, IL

Photo No. AO317-SCN92-300-3338. This photo shows a closeup view of the STINGER missile container laying outside of the MILVAN.

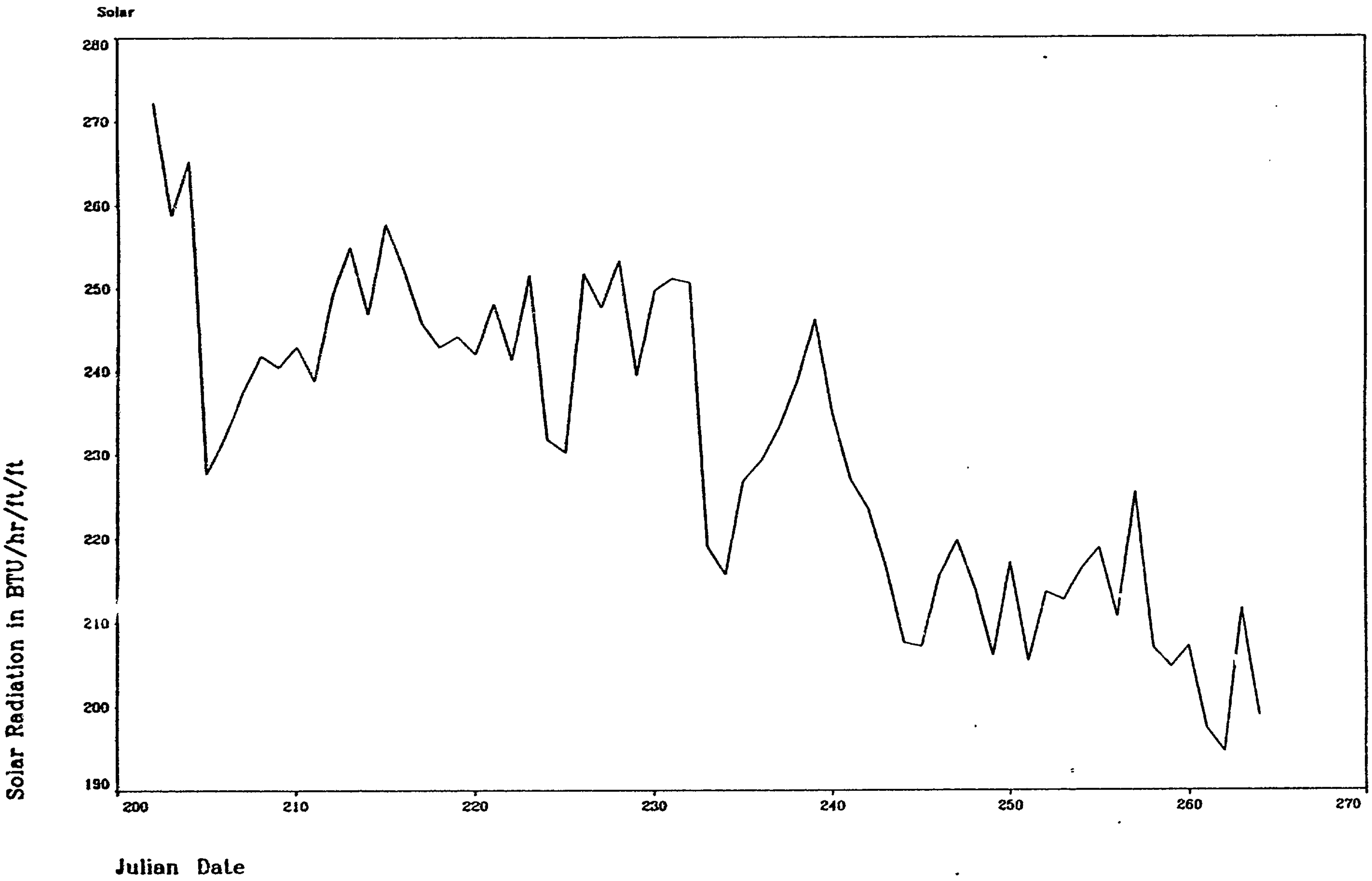
PART 6

GRAPHS

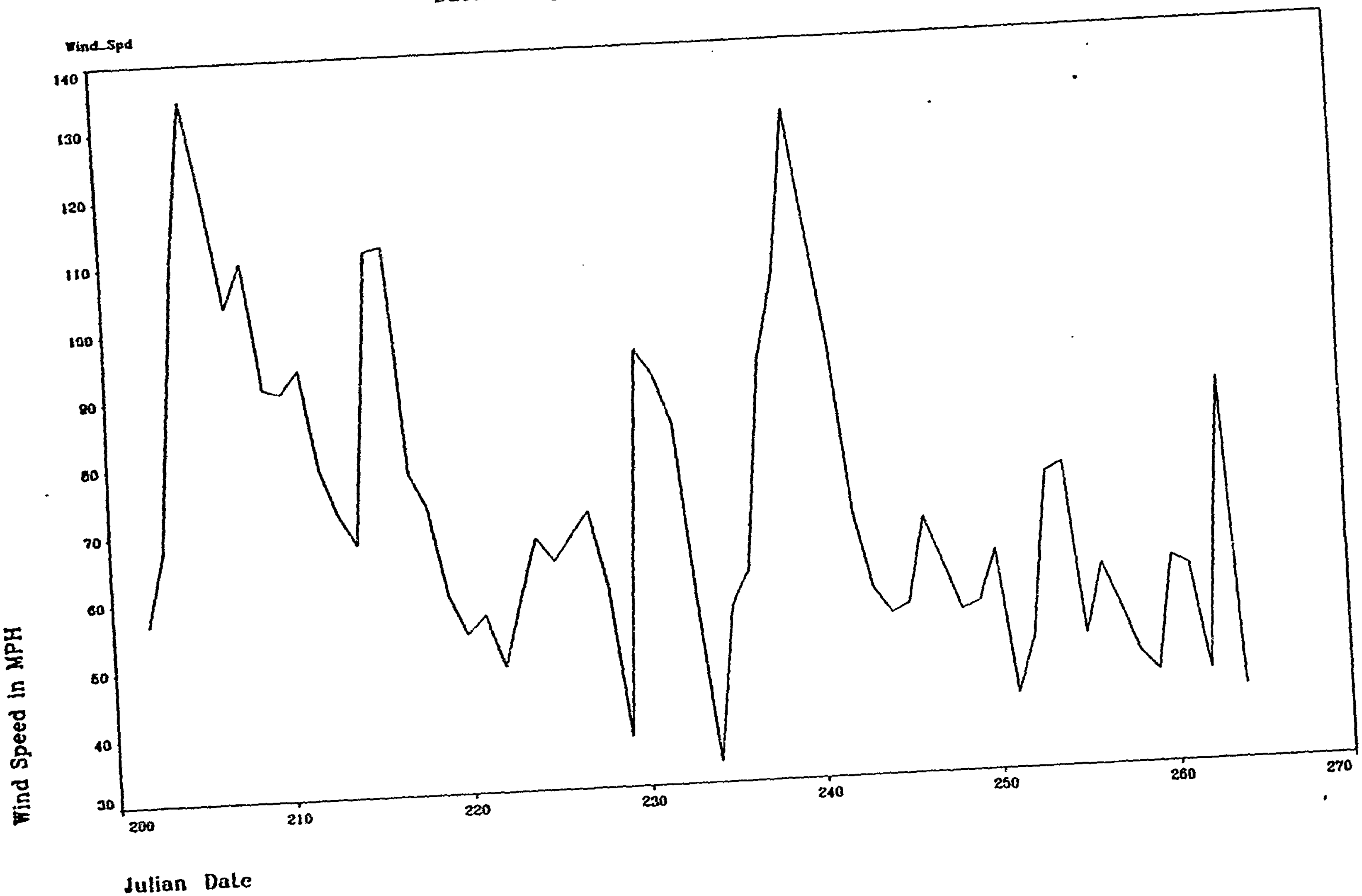
Results from Kuwait Slinger Temperature Monitoring
Date: July 20 - Sept 20, 1992



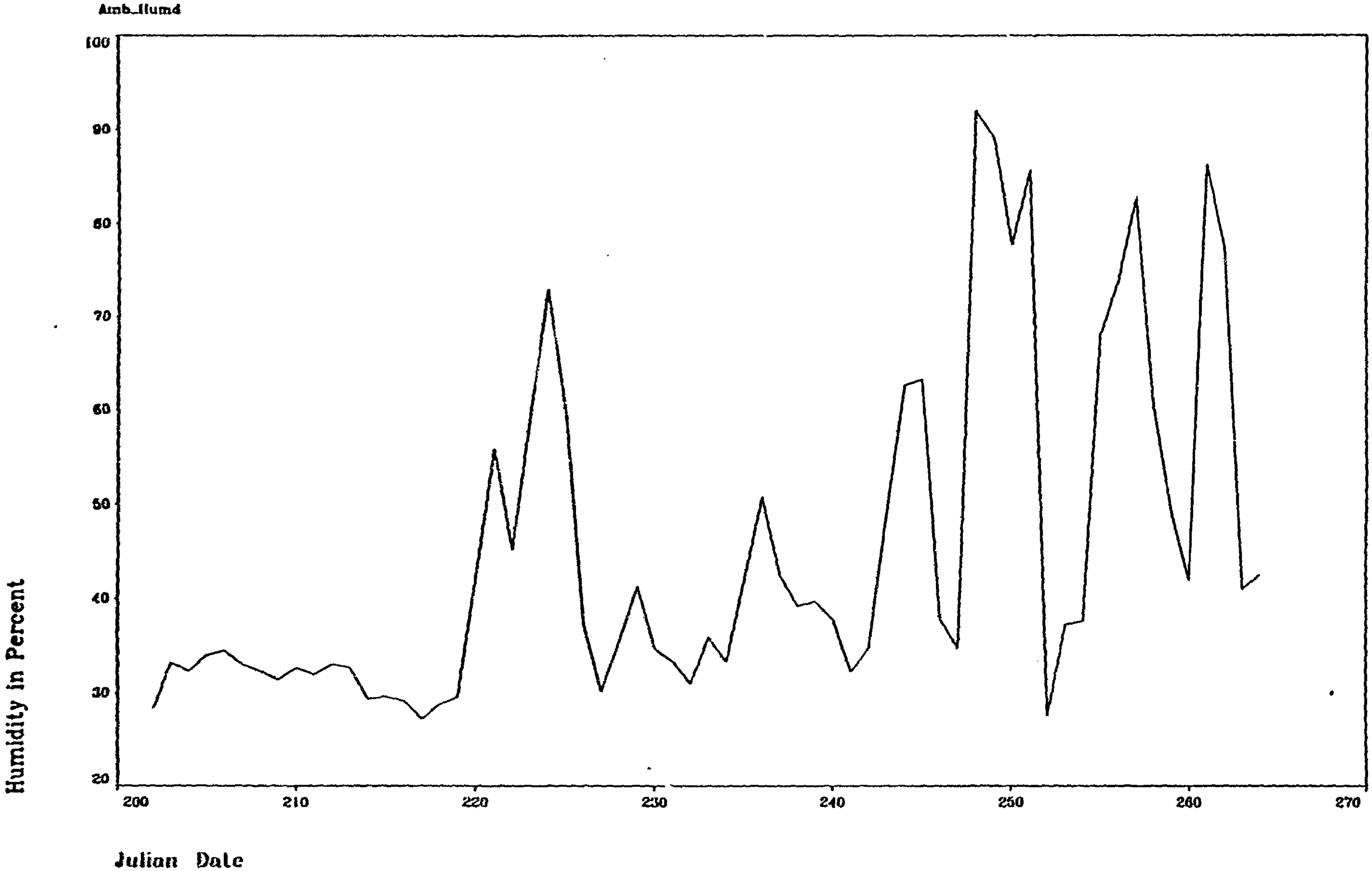
Results from Kuwait Stinger Temperature Monitoring
Date: July 20 - Sept 20, 1992

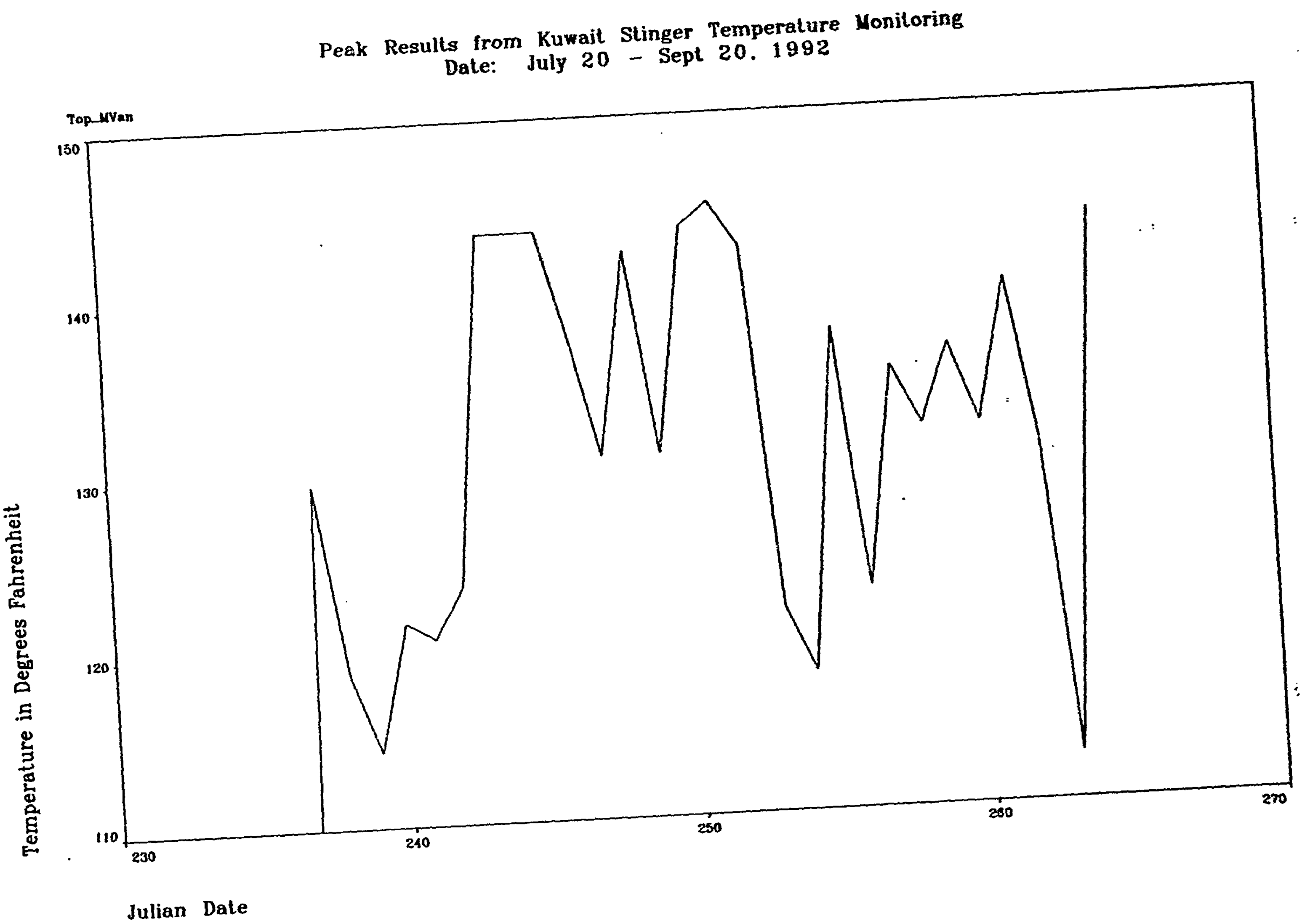


Results from Kuwait Stinger Temperature Monitoring
Date: July 20 - Sept 20, 1992



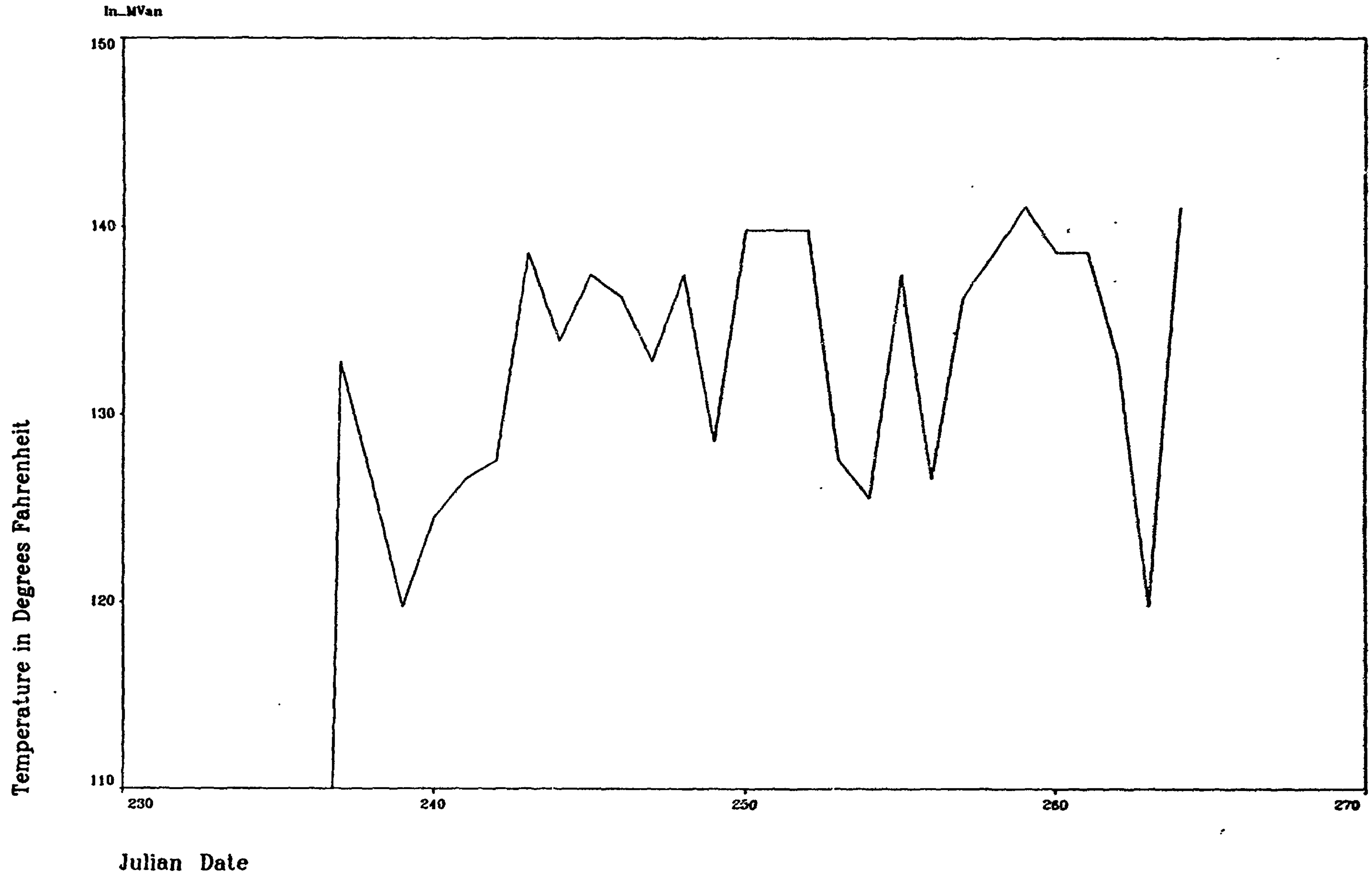
Results from Kuwait Slinger Temperature Monitoring
Date: July 20 – Sept 20, 1992



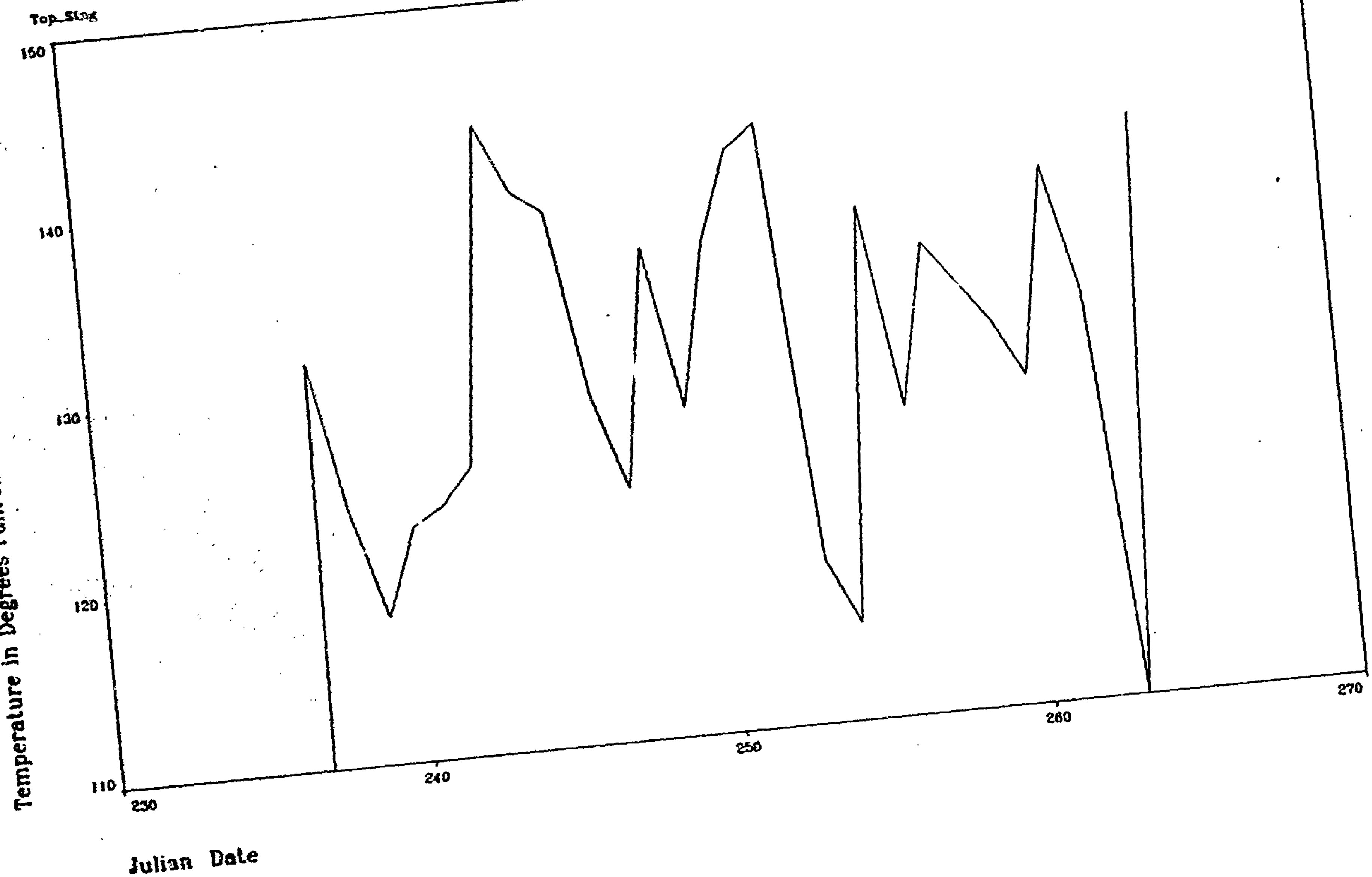


Peak Results from Kuwait Stinger Temperature Monitoring
Date: July 20 - Sept 20. 1992
Top_MVan
150
140
130
120
110
230
240
250
260
270
Temperature in Degrees Fahrenheit
Julian Date

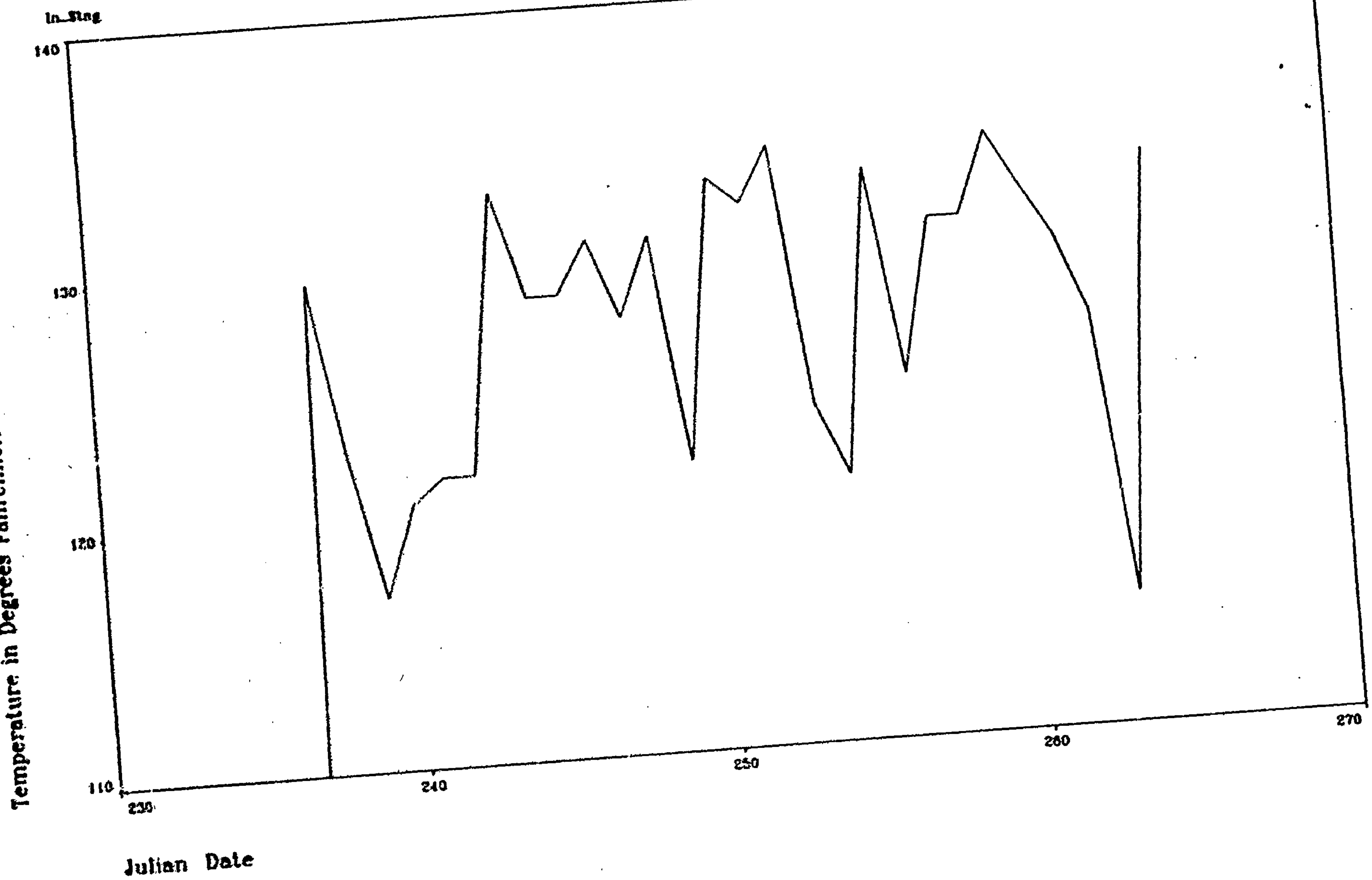
Peak Results from Kuwait Stinger Temperature Monitoring
Date: July 20 - Sept 20, 1992



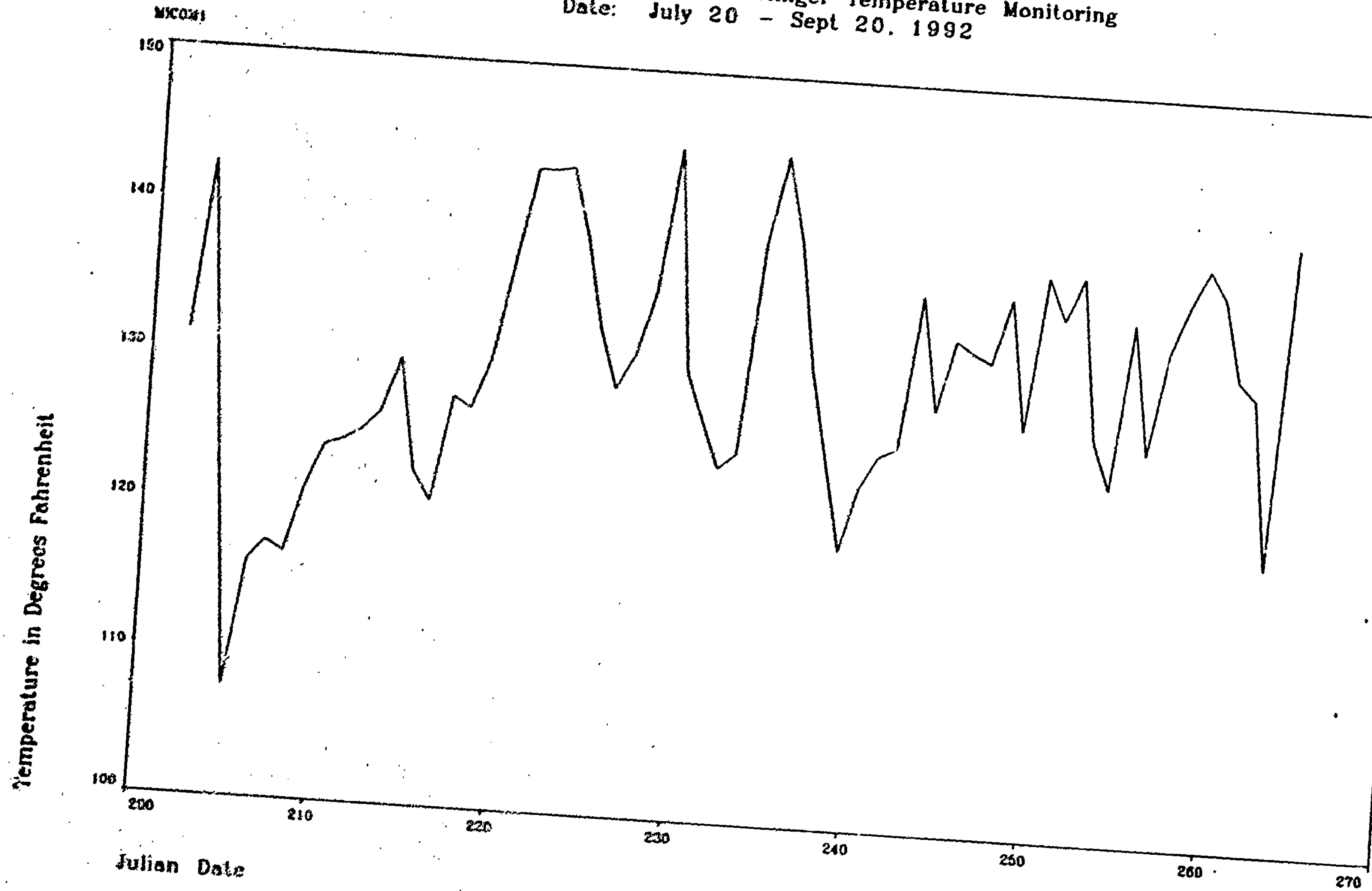
Peak Results from Kuwait Slinger Temperature Monitoring
Date: July 20 - Sept 20, 1992

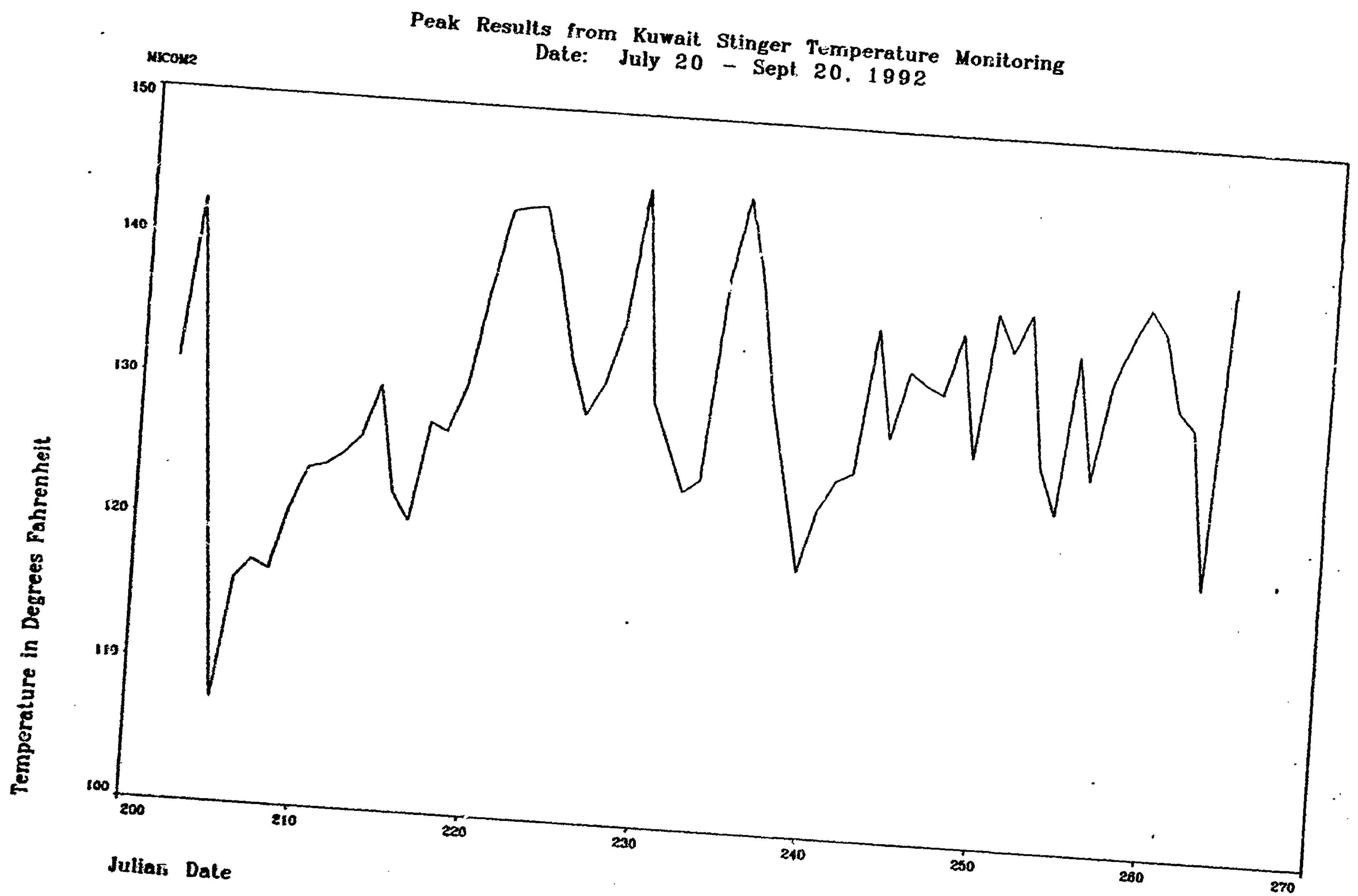


Peak Results from Kuwait Stinger Temperature Monitoring
Date: July 20 - Sept 20, 1992



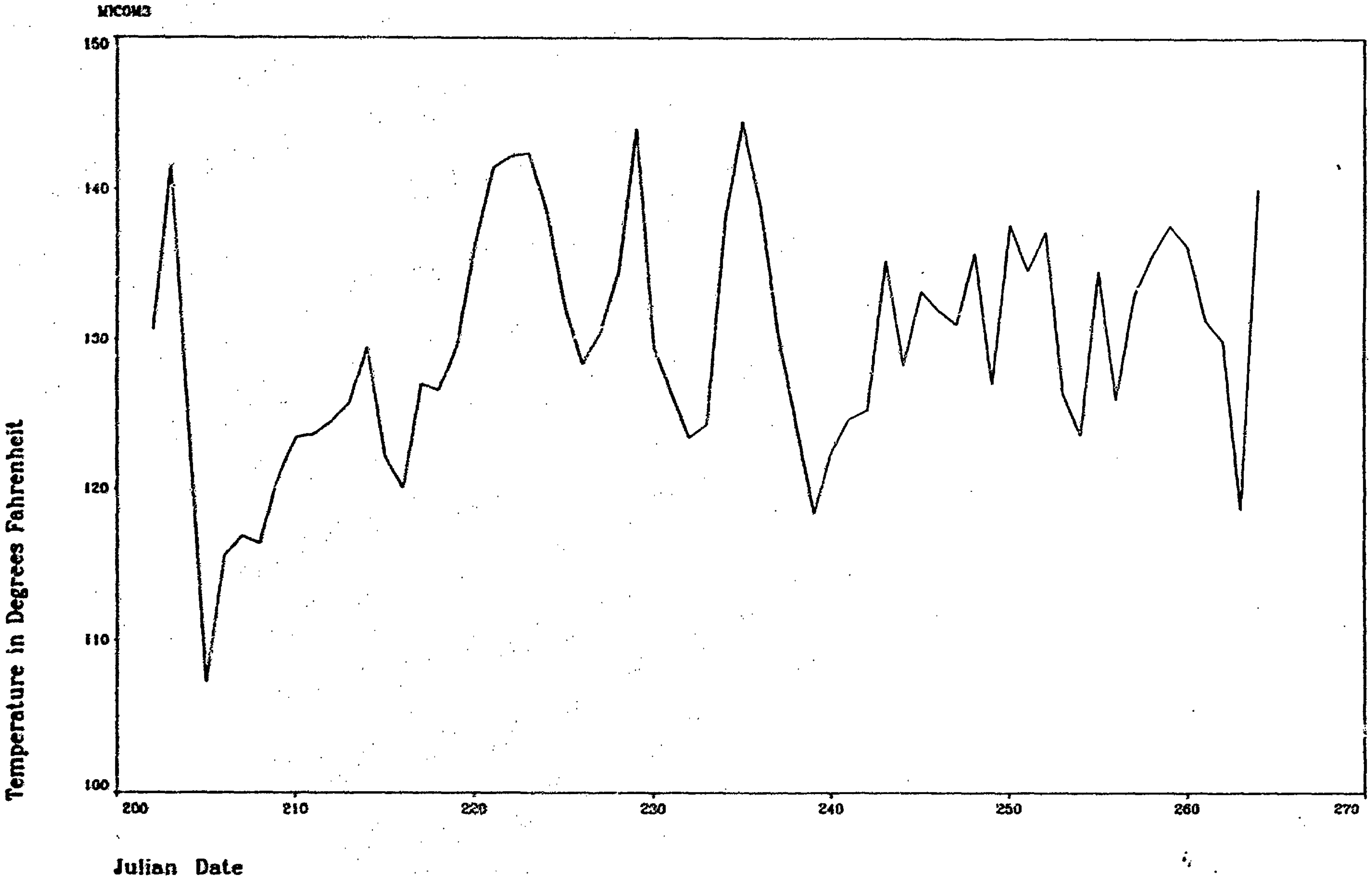
Peak Results from Kuwait Stinger Temperature Monitoring
Date: July 20 - Sept 20, 1992



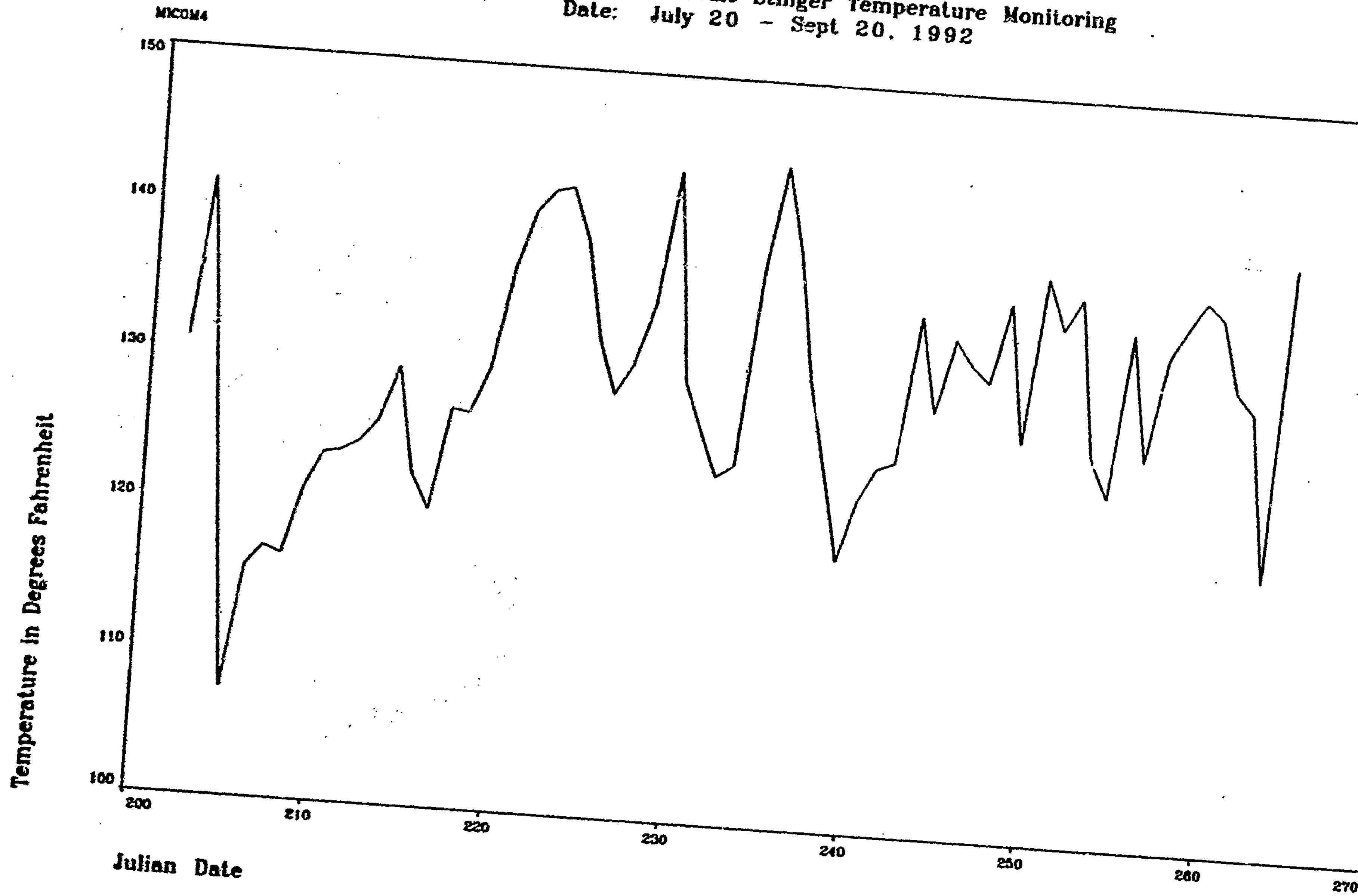


Peak Results from Kuwait Stinger Temperature Monitoring
Date: July 20 - Sept 20, 1992
NICOM2
150
140
130
120
110
100
200
210
220
230
240
250
260
270
Julian Date
Temperature in Degrees Fahrenheit

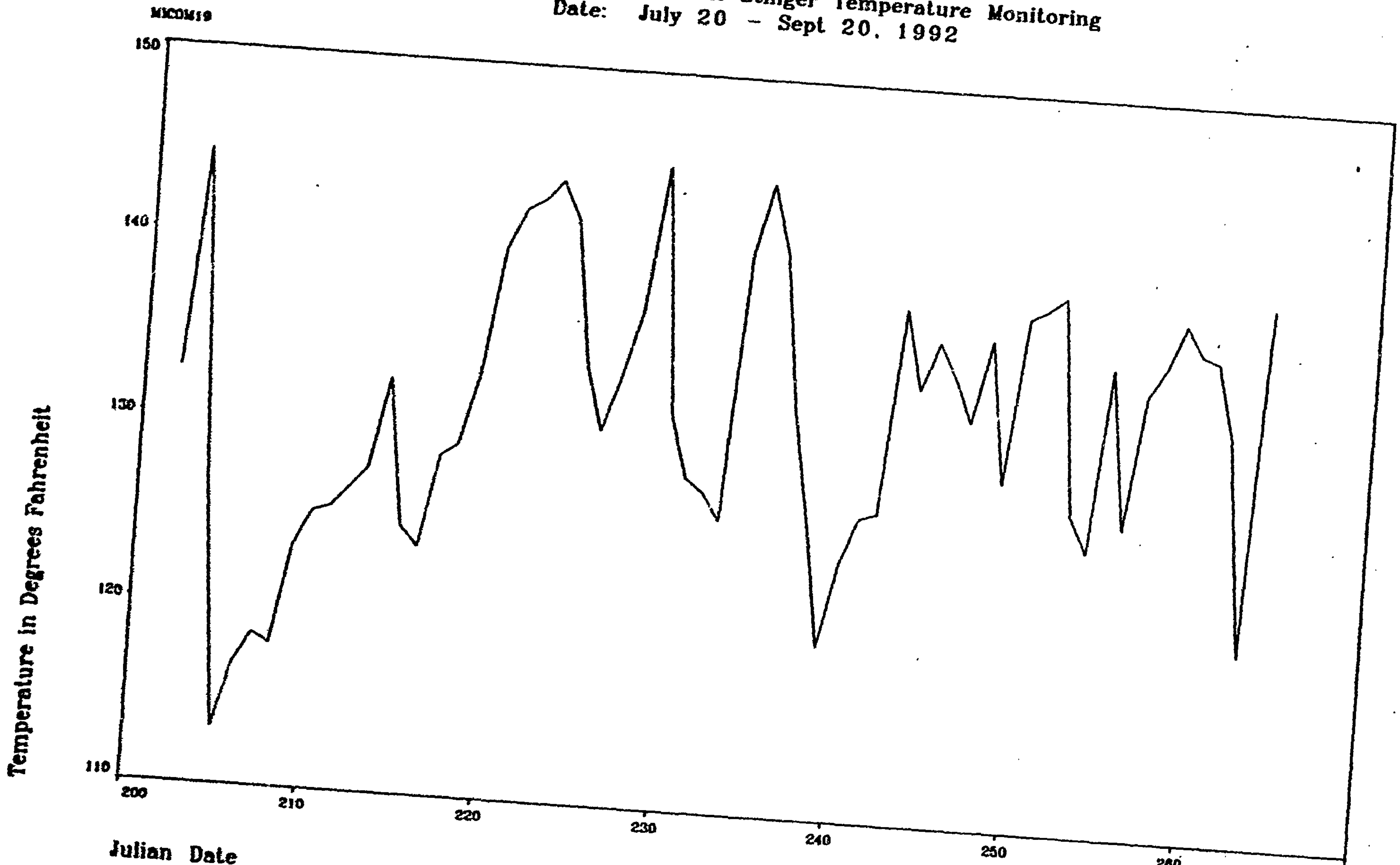
Peak Results from Kuwait Stinger Temperature Monitoring
Date: July 20 - Sept 20, 1992

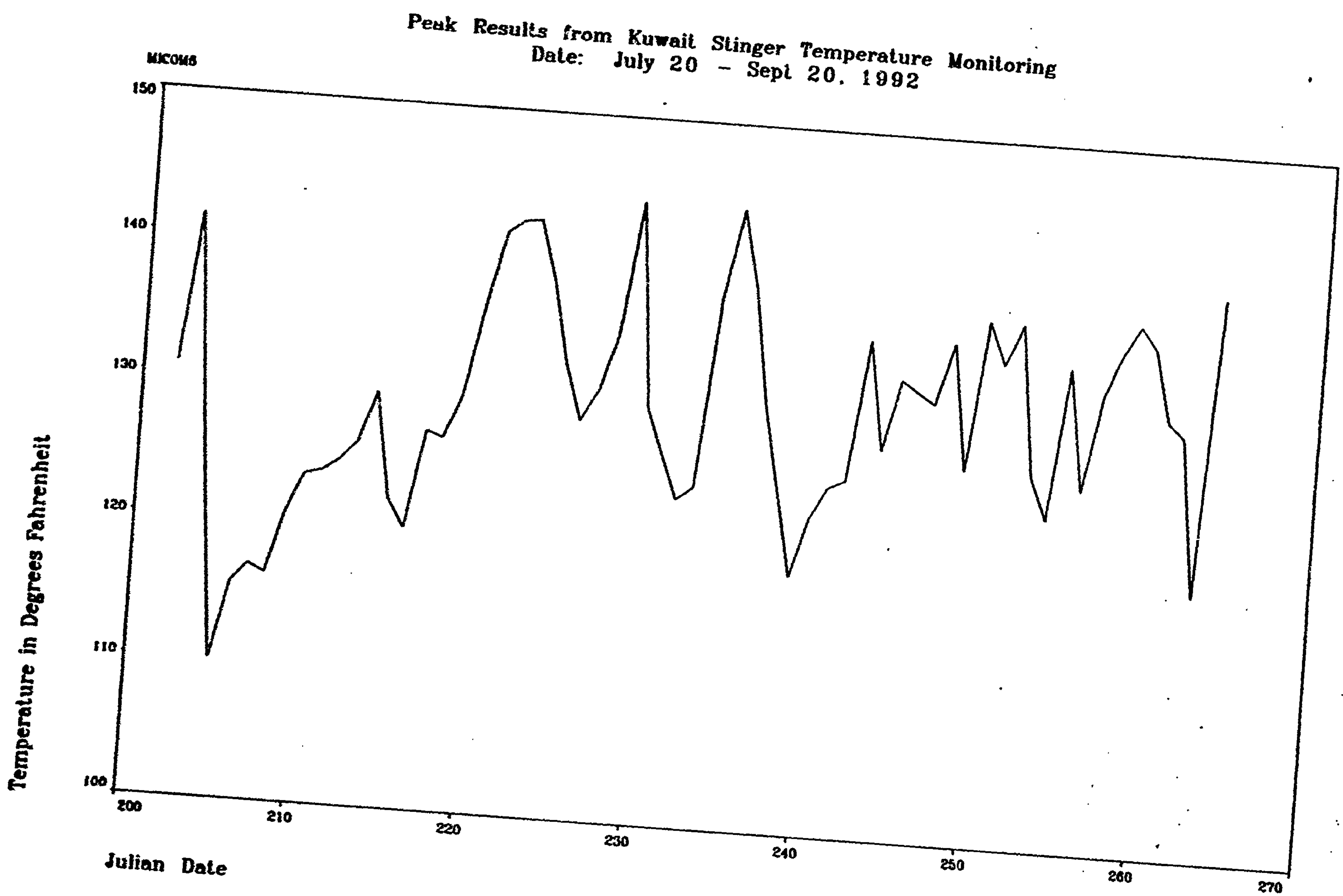


Peak Results from Kuwait Stinger Temperature Monitoring
Date: July 20 - Sept 20, 1992

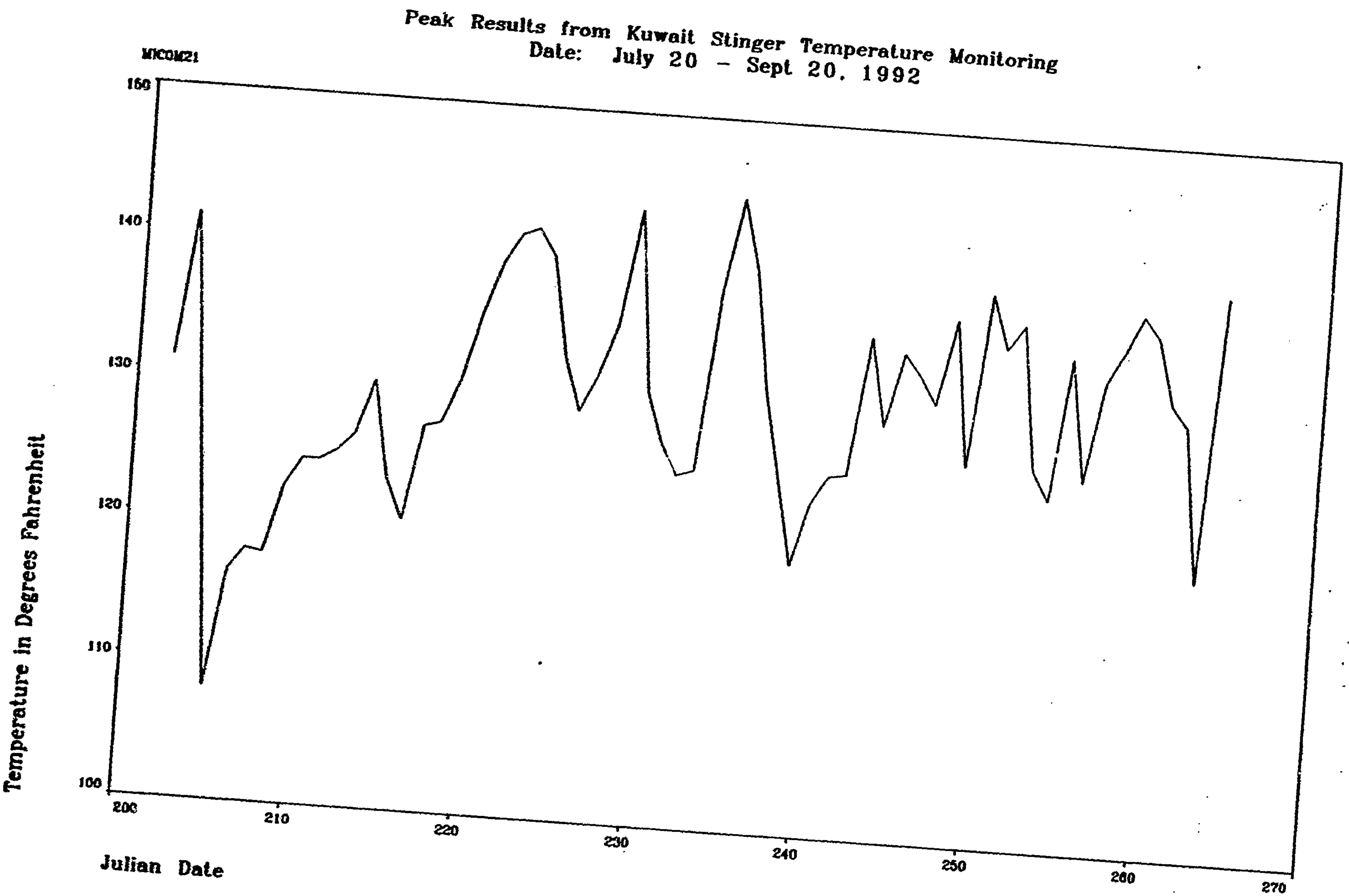


Peak Results from Kuwait Stinger Temperature Monitoring
Date: July 20 - Sept 20, 1992



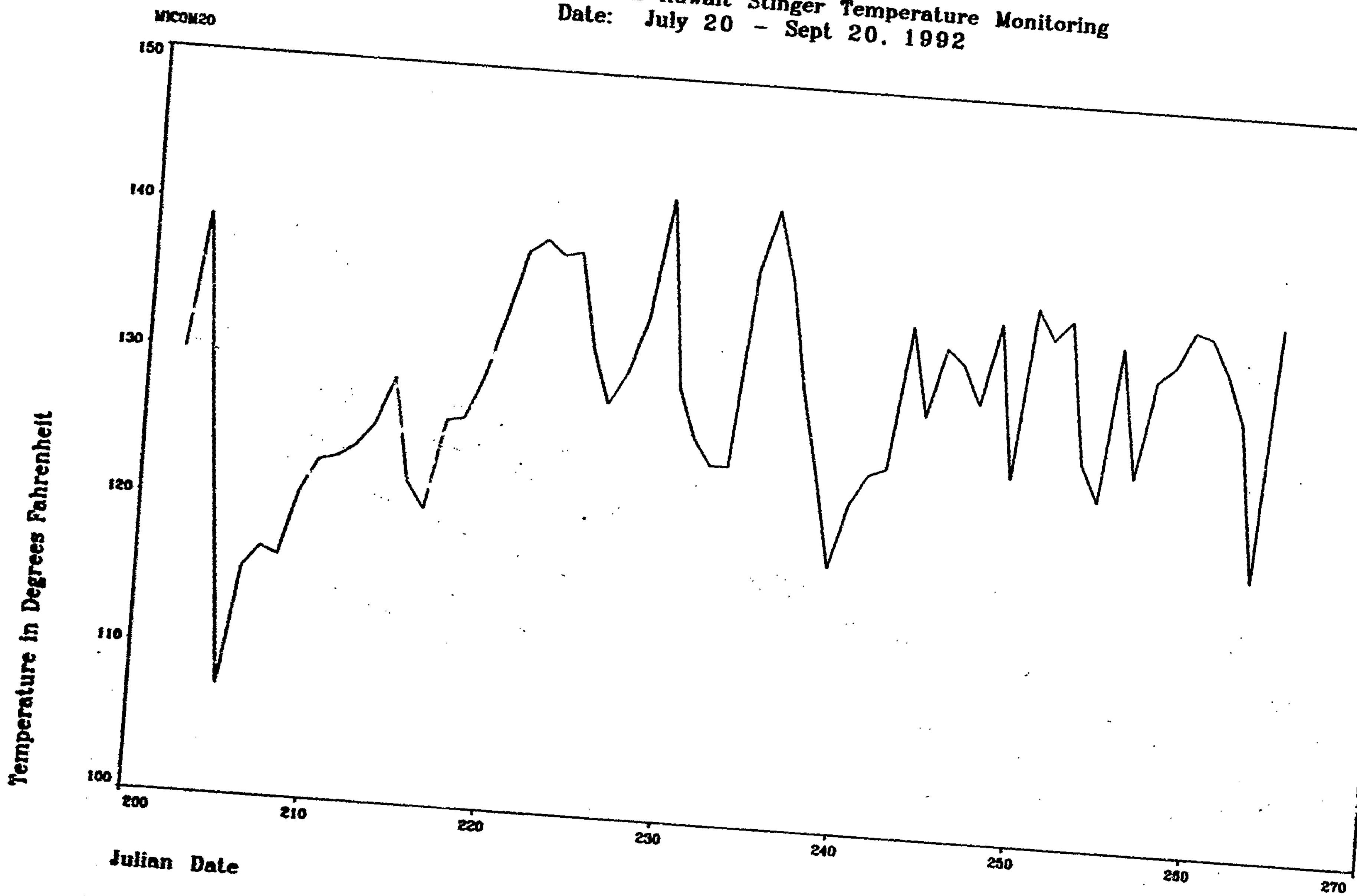


Peak Results from Kuwait Stinger Temperature Monitoring
Date: July 20 - Sept 20, 1992
MKOMS
150
140
130
120
110
100
200
210
220
230
240
250
260
270
Julian Date
Temperature in Degrees Fahrenheit

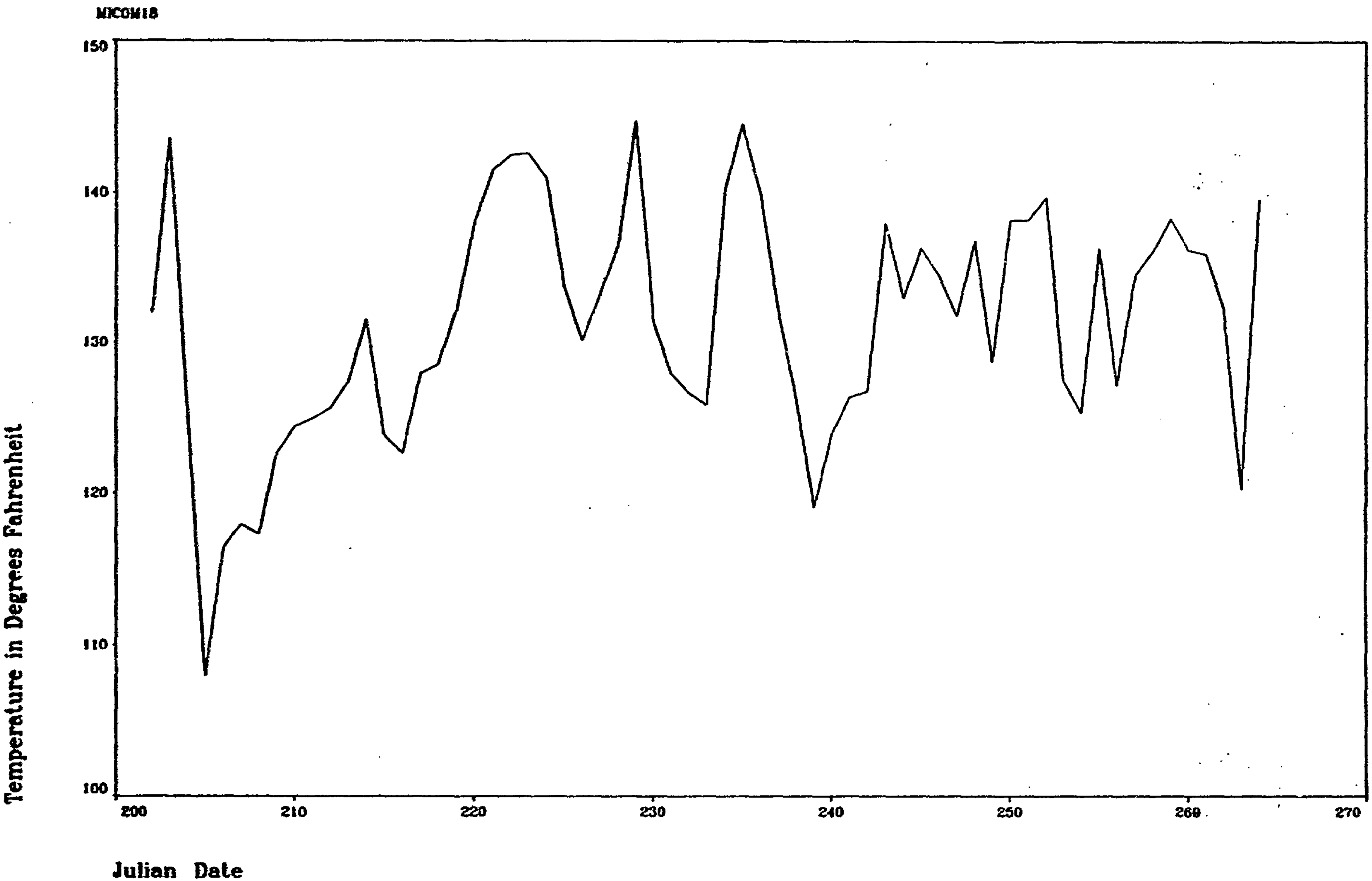


Peak Results from Kuwait Stinger Temperature Monitoring
Date: July 20 - Sept 20, 1992
MICOM21
150
140
130
120
110
100
200
210
220
230
240
250
260
270
Temperature in Degrees Fahrenheit
Julian Date

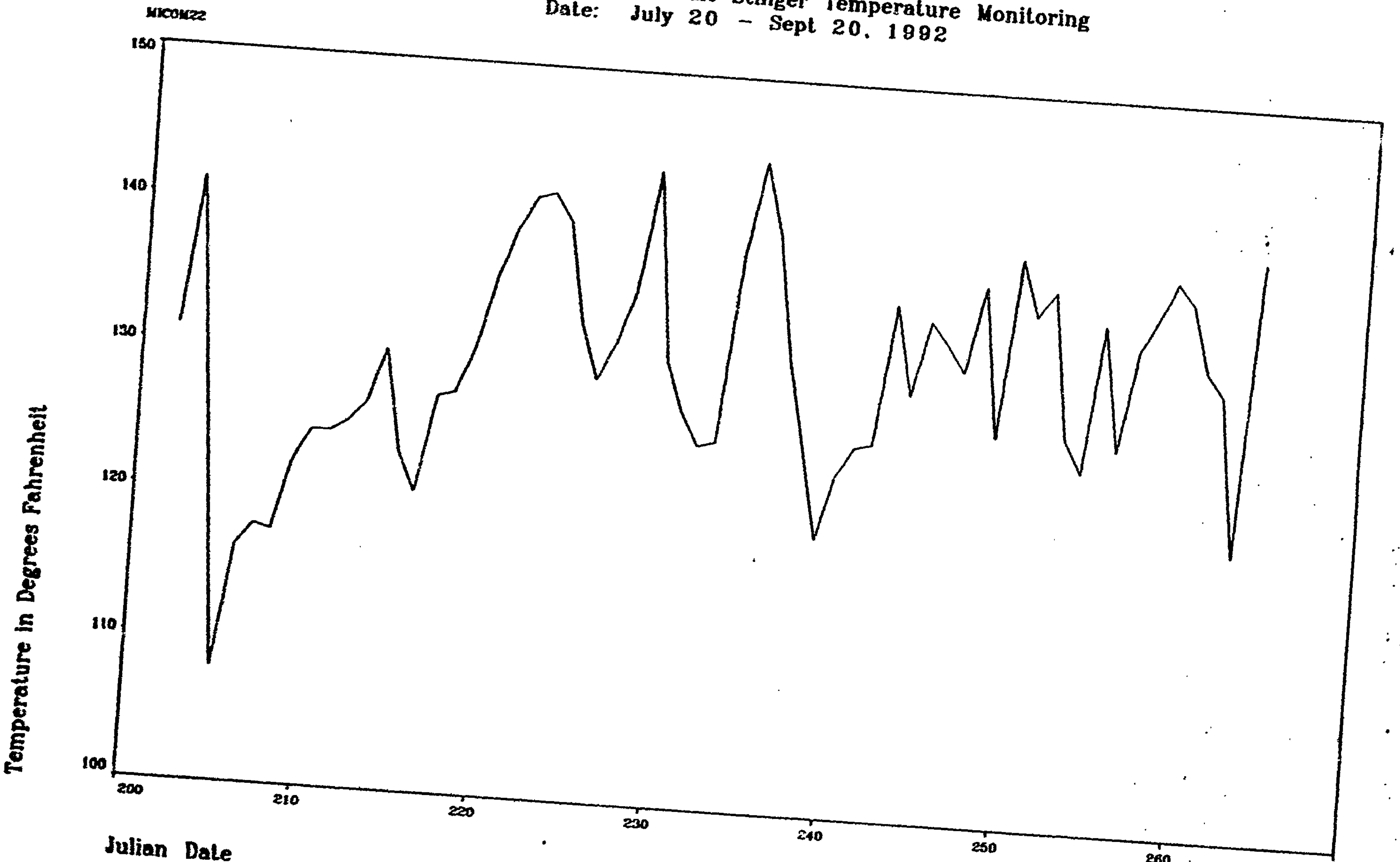
Peak Results from Kuwait Stinger Temperature Monitoring
Date: July 20 - Sept 20, 1992



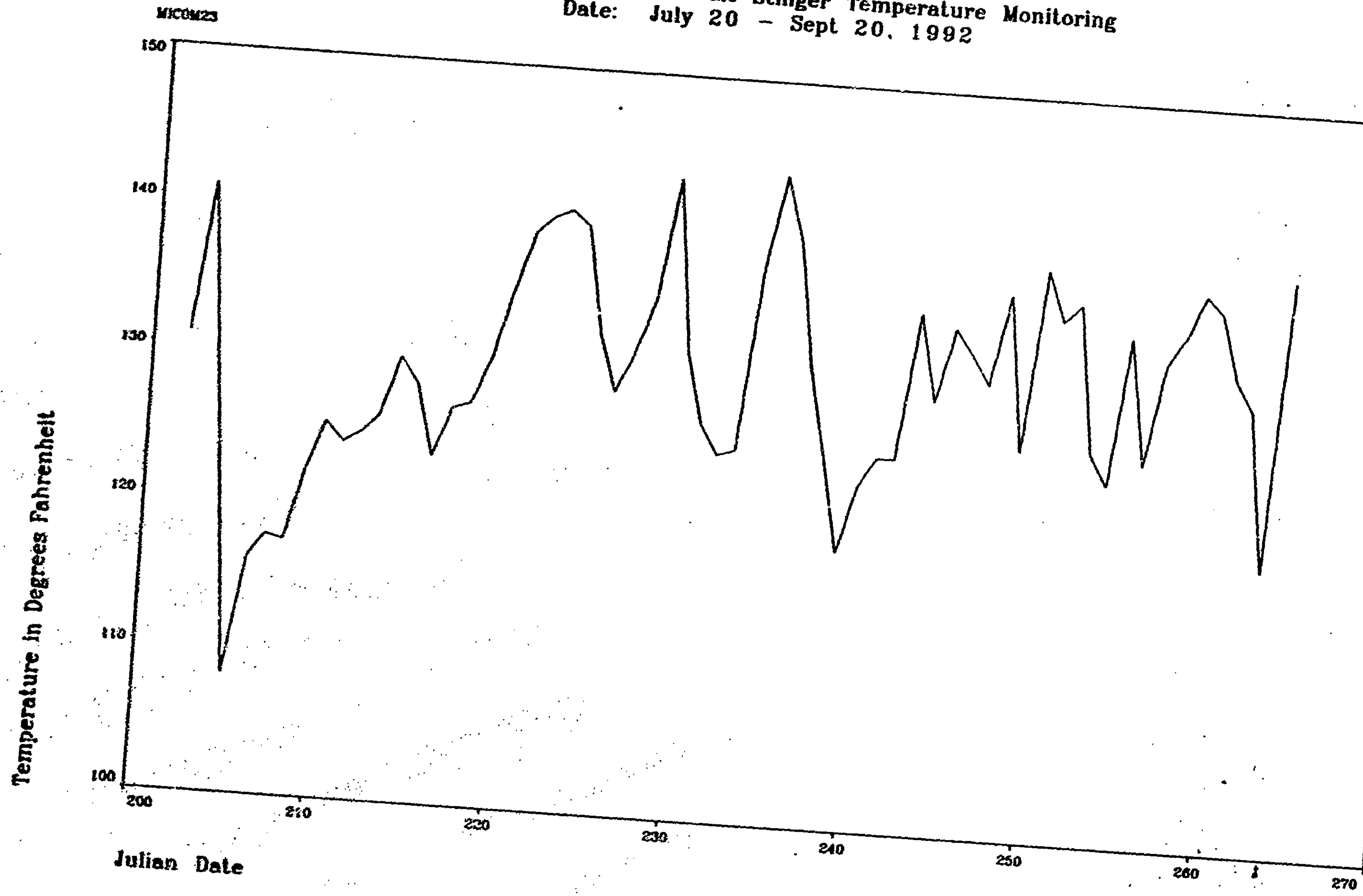
Peak Results from Kuwait Stinger Temperature Monitoring
Date: July 20 - Sept 20, 1992



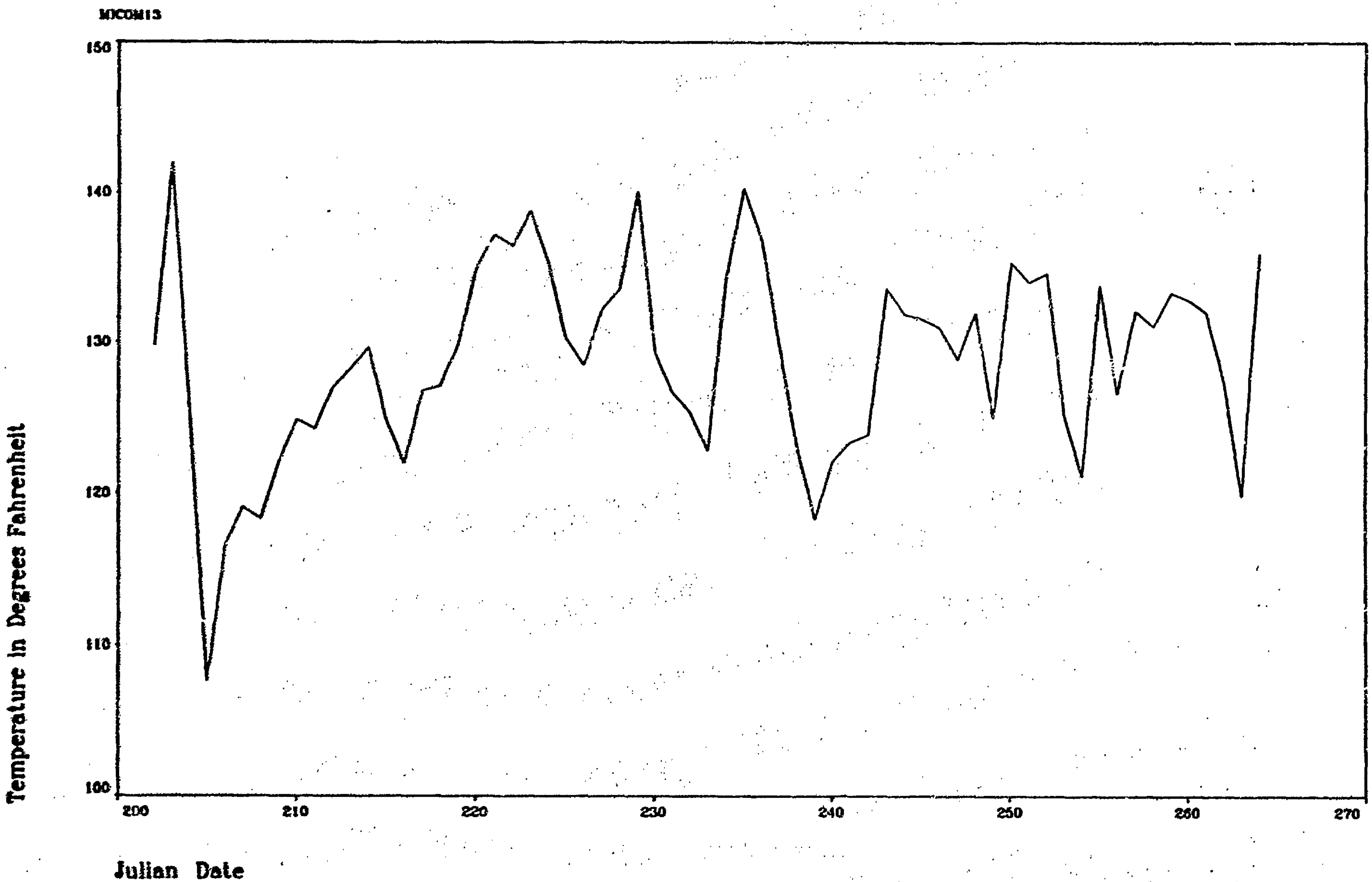
Peak Results from Kuwait Stinger Temperature Monitoring
Date: July 20 - Sept 20, 1992



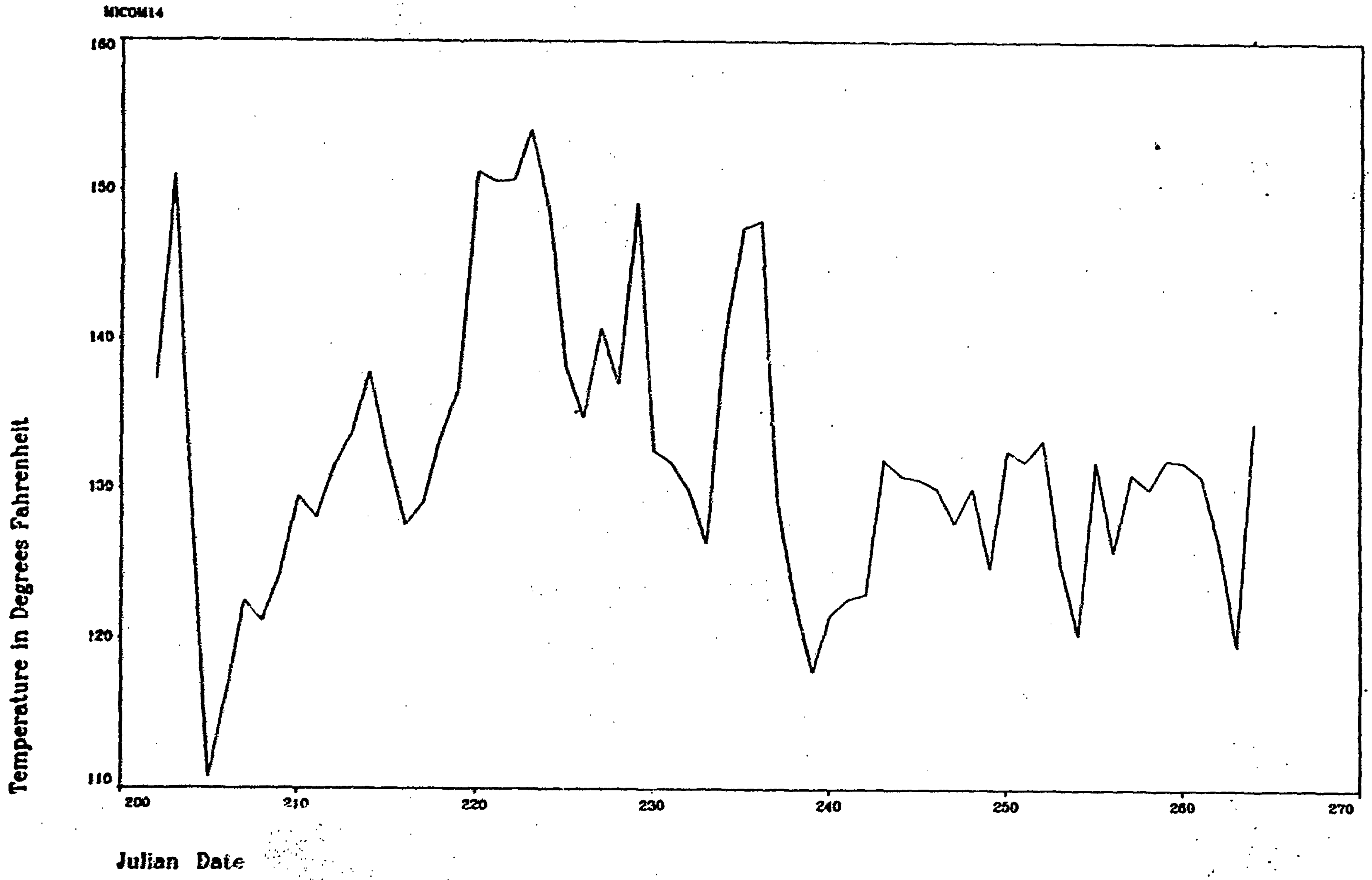
Peak Results from Kuwait Stinger Temperature Monitoring
Date: July 20 - Sept 20, 1992



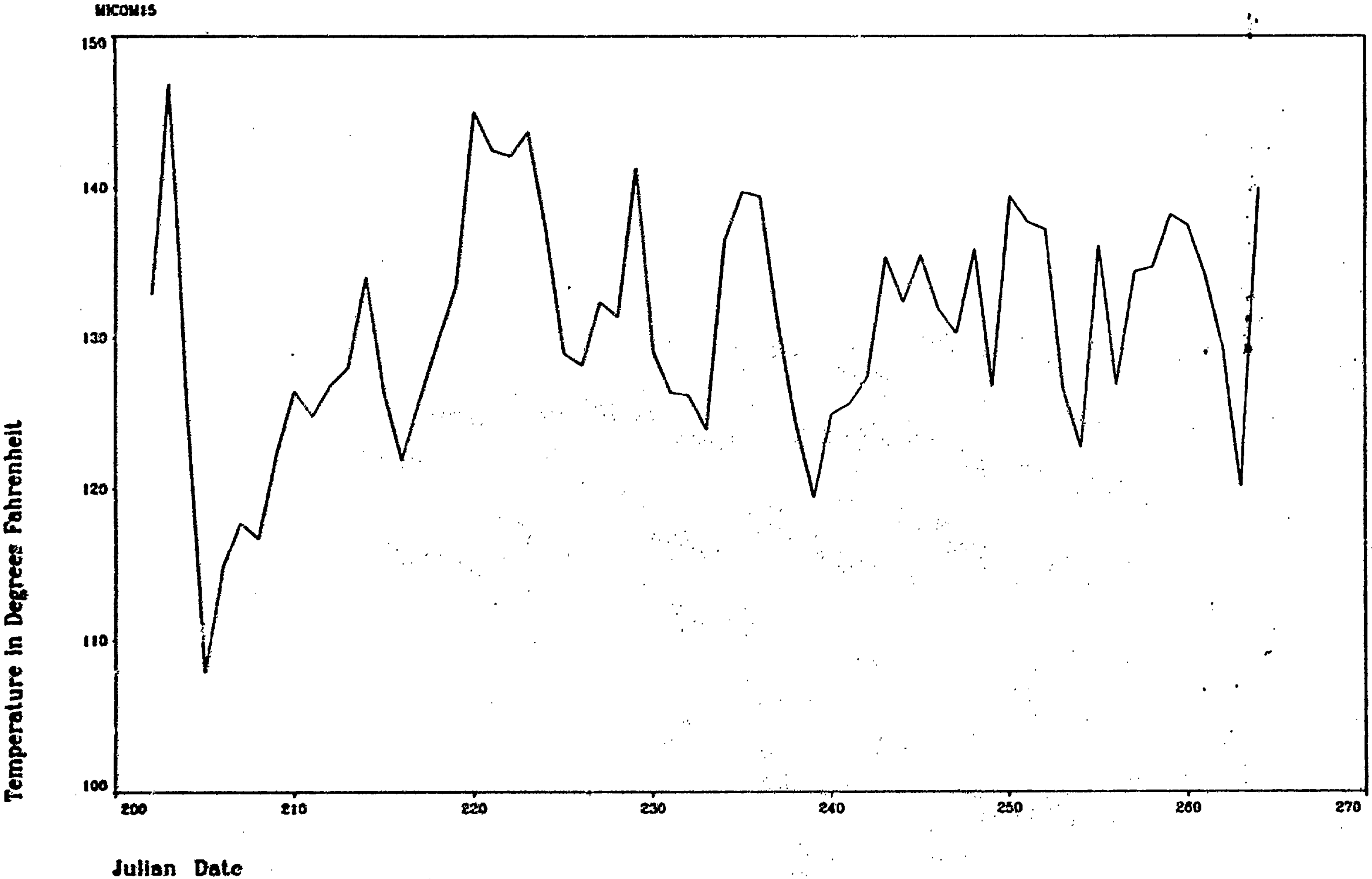
Peak Results from Kuwait Stinger Temperature Monitoring
Date: July 20 – Sept 20, 1992



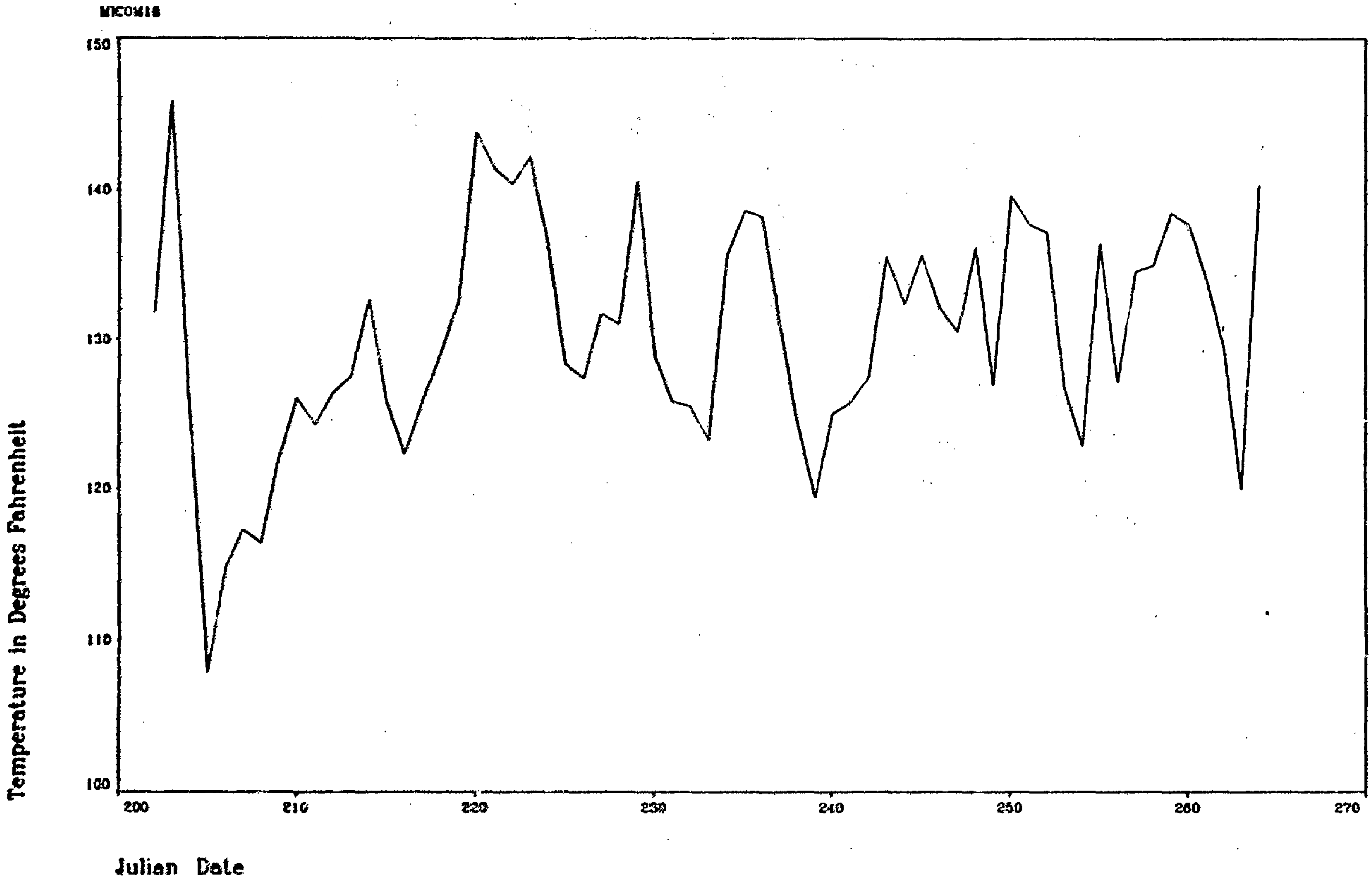
Peak Results from Kuwait Stinger Temperature Monitoring
Date: July 20 - Sept 20, 1992



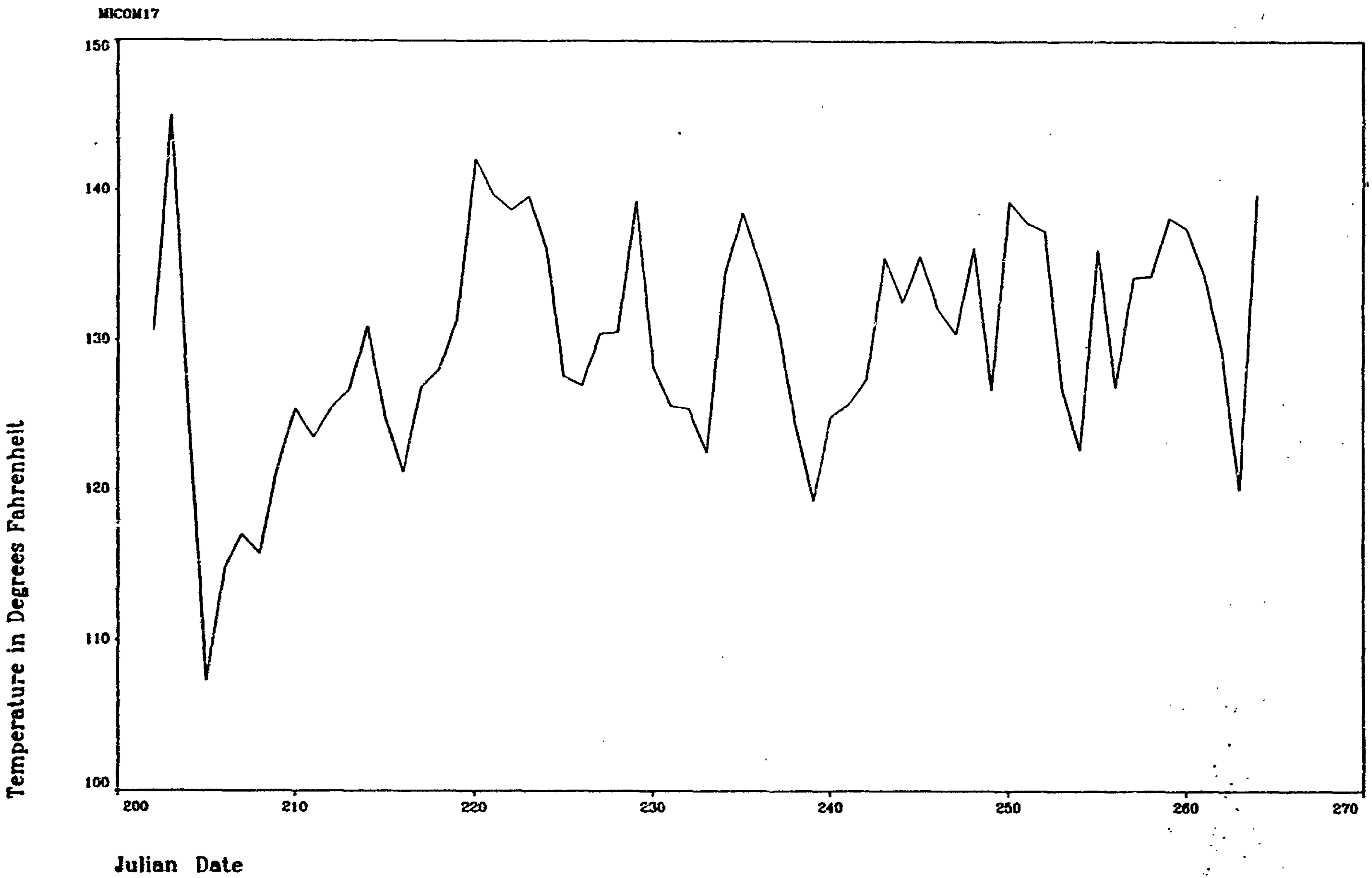
Peak Results from Kuwait Stinger Temperature Monitoring
Date: July 20 - Sept 20, 1992

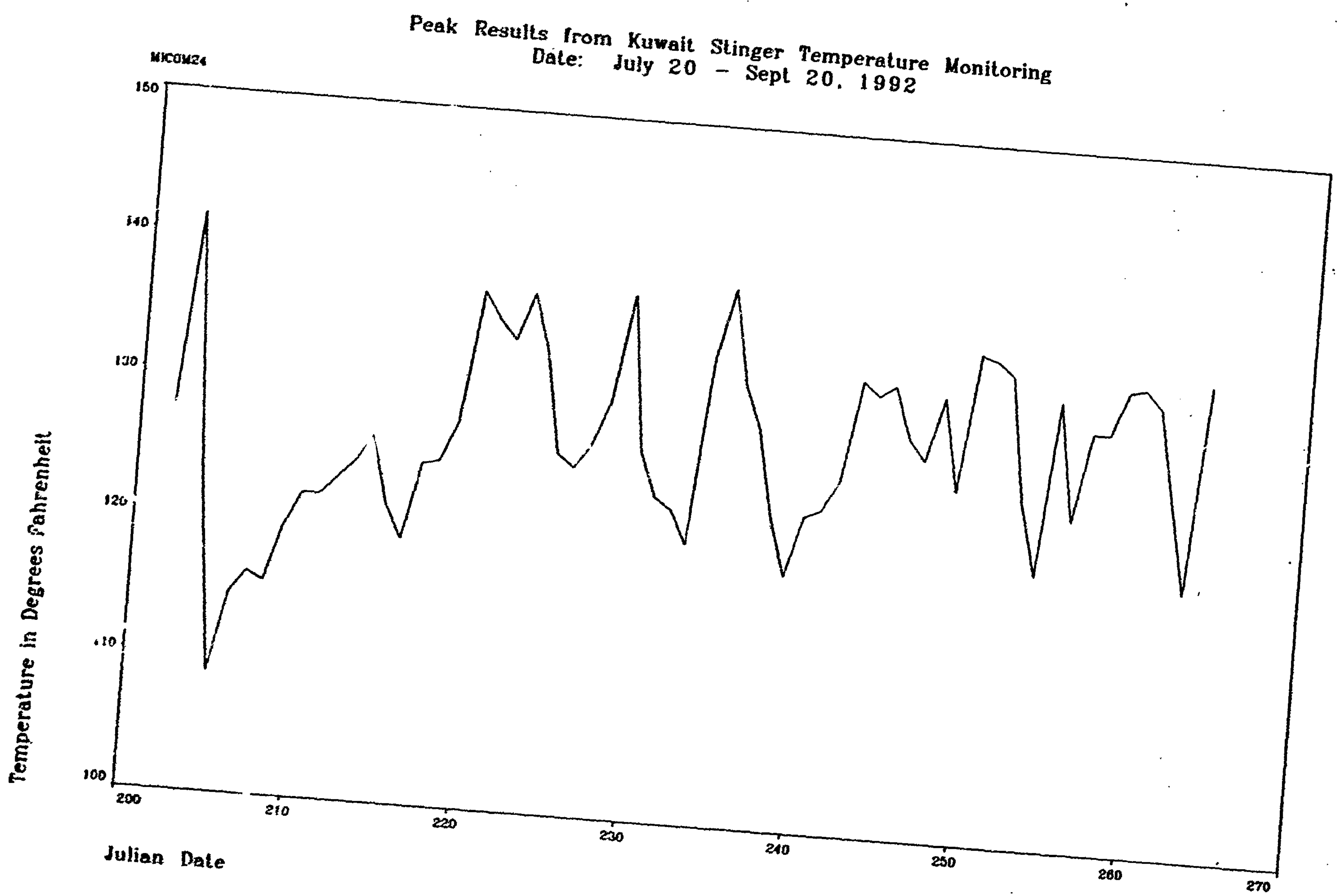


Peak Results from Kuwait Stinger Temperature Monitoring
Date: July 20 -- Sept 20, 1992

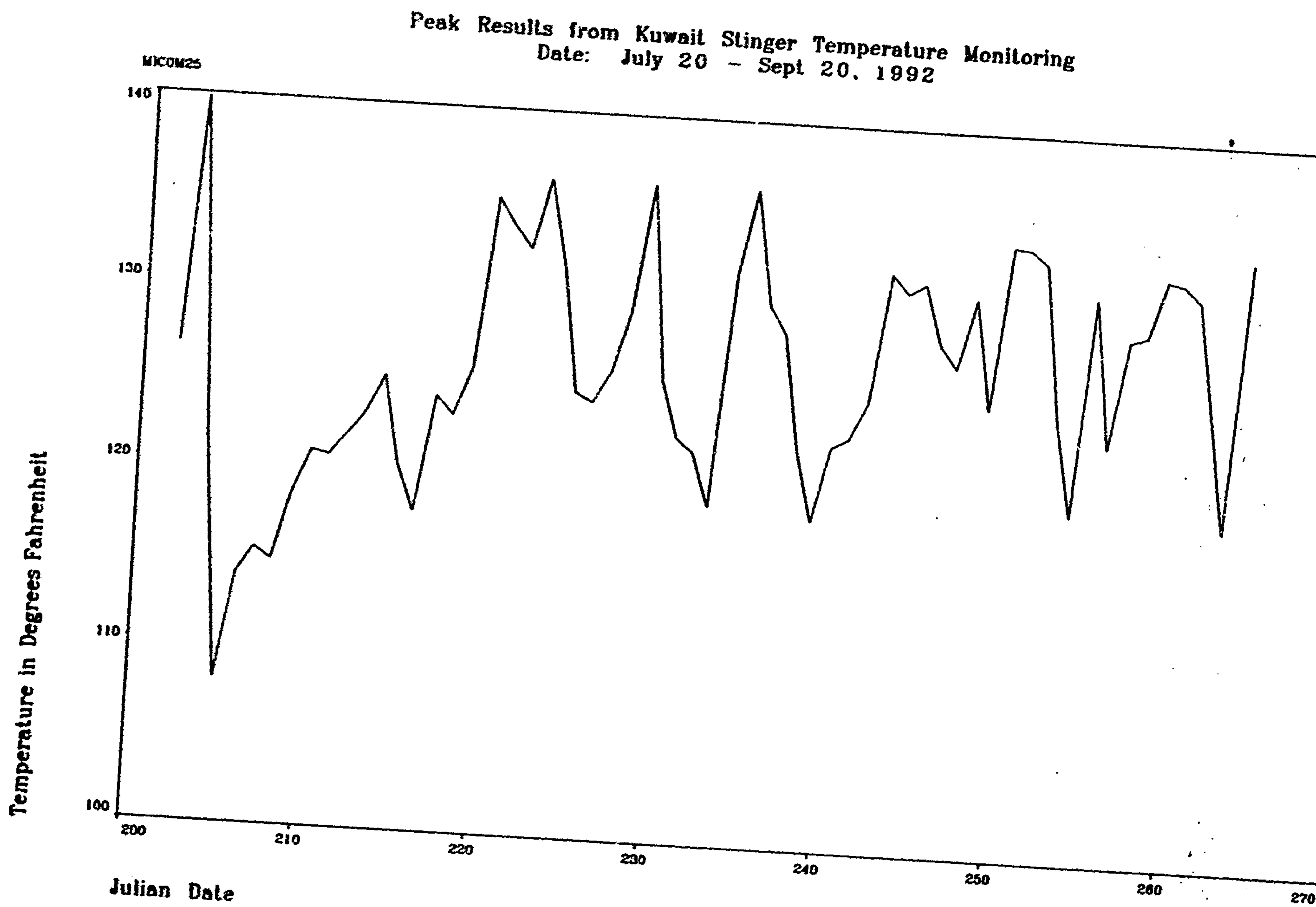


Peak Results from Kuwait Stinger Temperature Monitoring
Date: July 20 – Sept 20, 1992

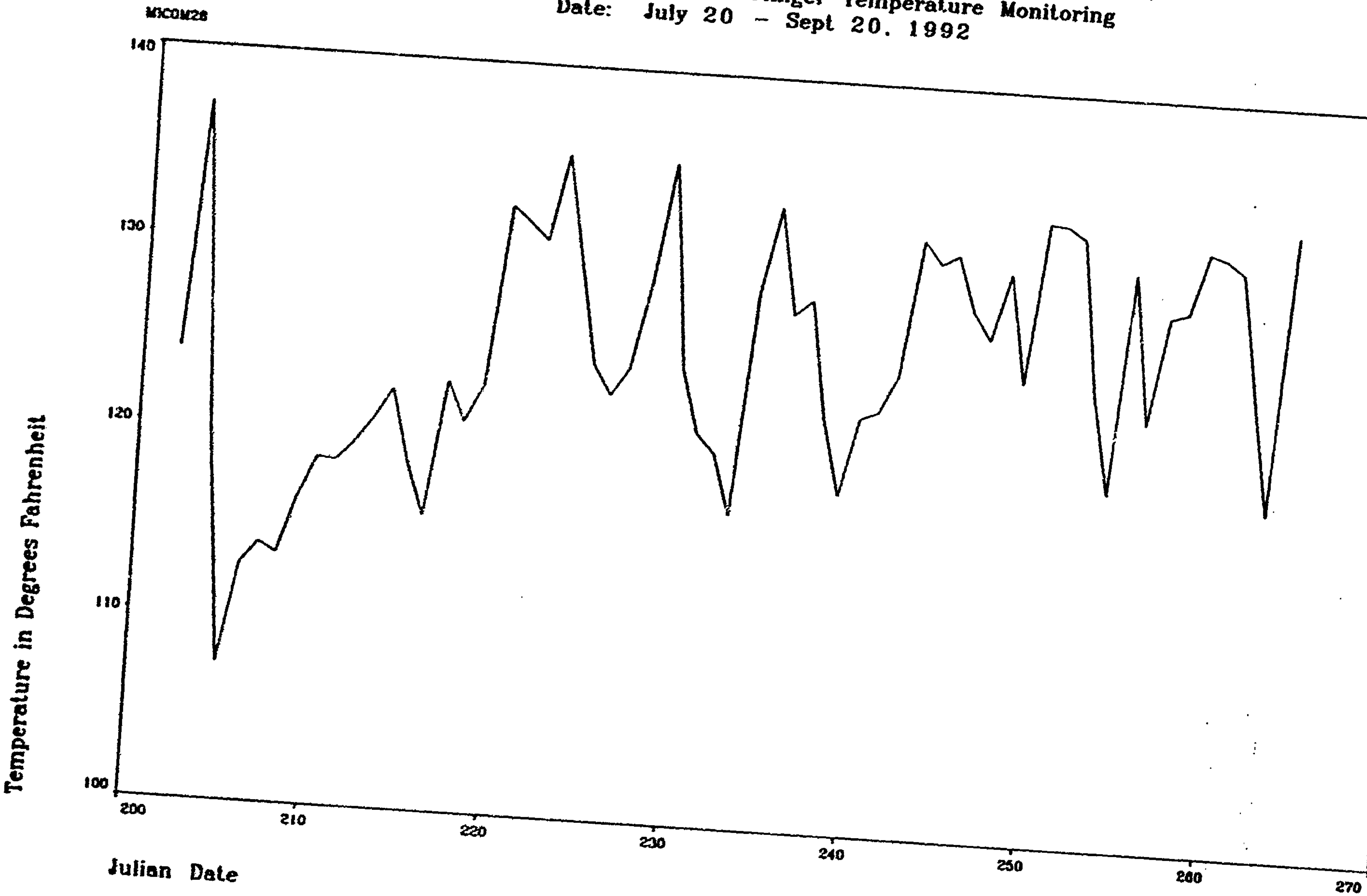




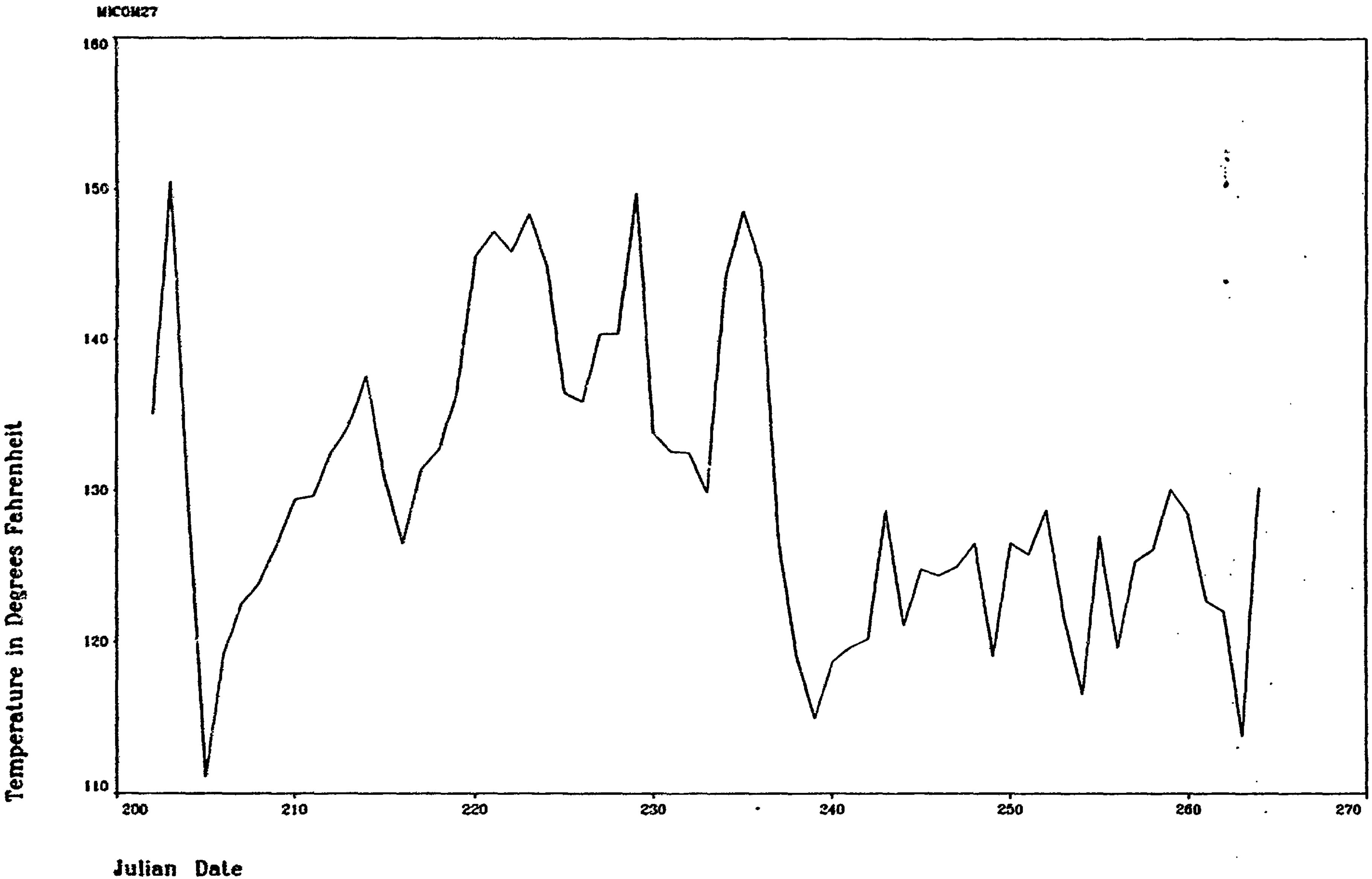
Peak Results from Kuwait Stinger Temperature Monitoring
Date: July 20 - Sept 20, 1992
MICOM24
150
140
130
120
110
100
200
210
220
230
240
250
260
270
Temperature in Degrees Fahrenheit
Julian Date

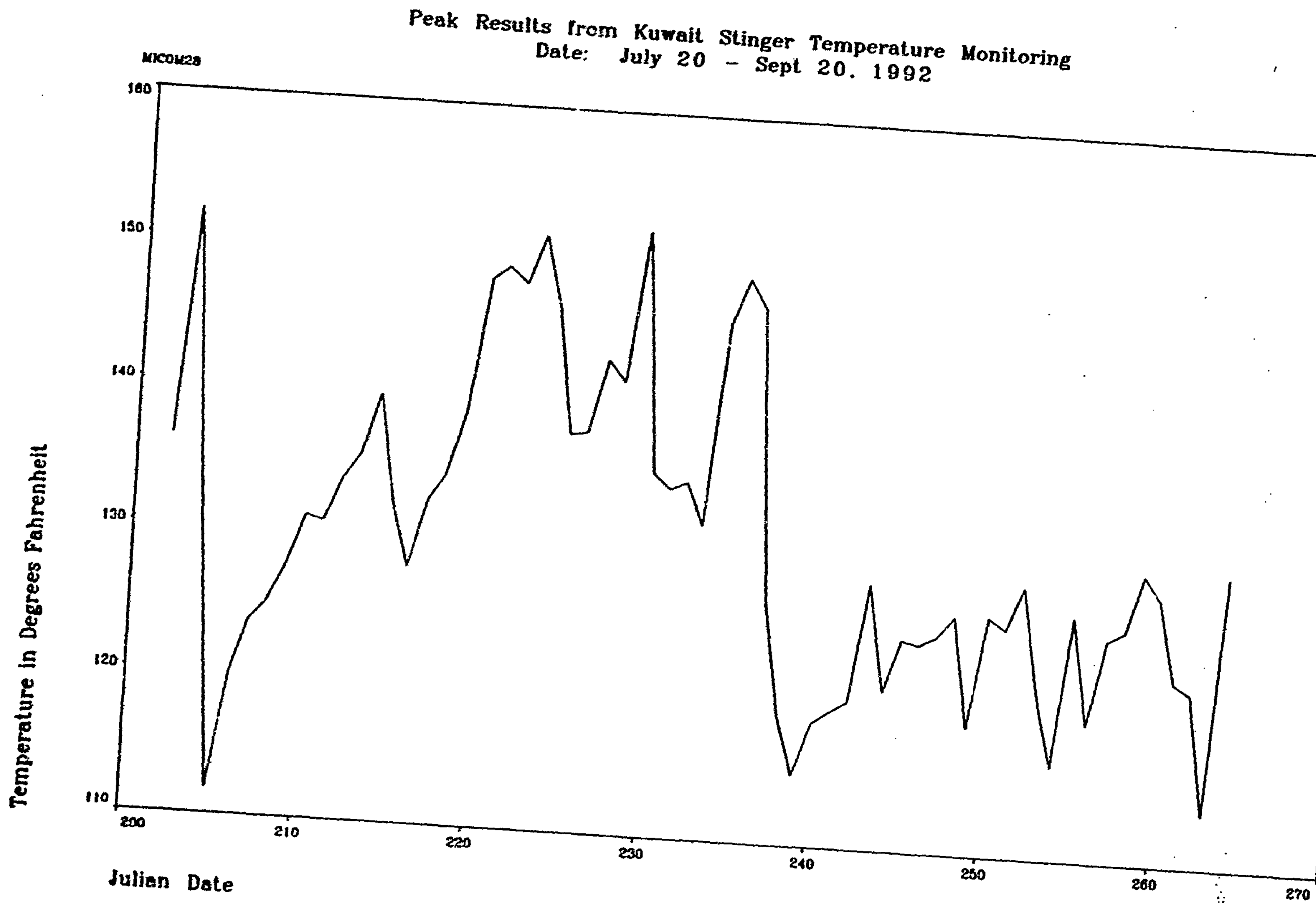

Peak Results from Kuwait Stinger Temperature Monitoring
Date: July 20 - Sept 20, 1992
MICOM25
Temperature in Degrees Fahrenheit
140
130
120
110
100
200
210
220
230
240
250
260
270
Julian Date

Peak Results from Kuwait Stinger Temperature Monitoring
Date: July 20 – Sept 20, 1992



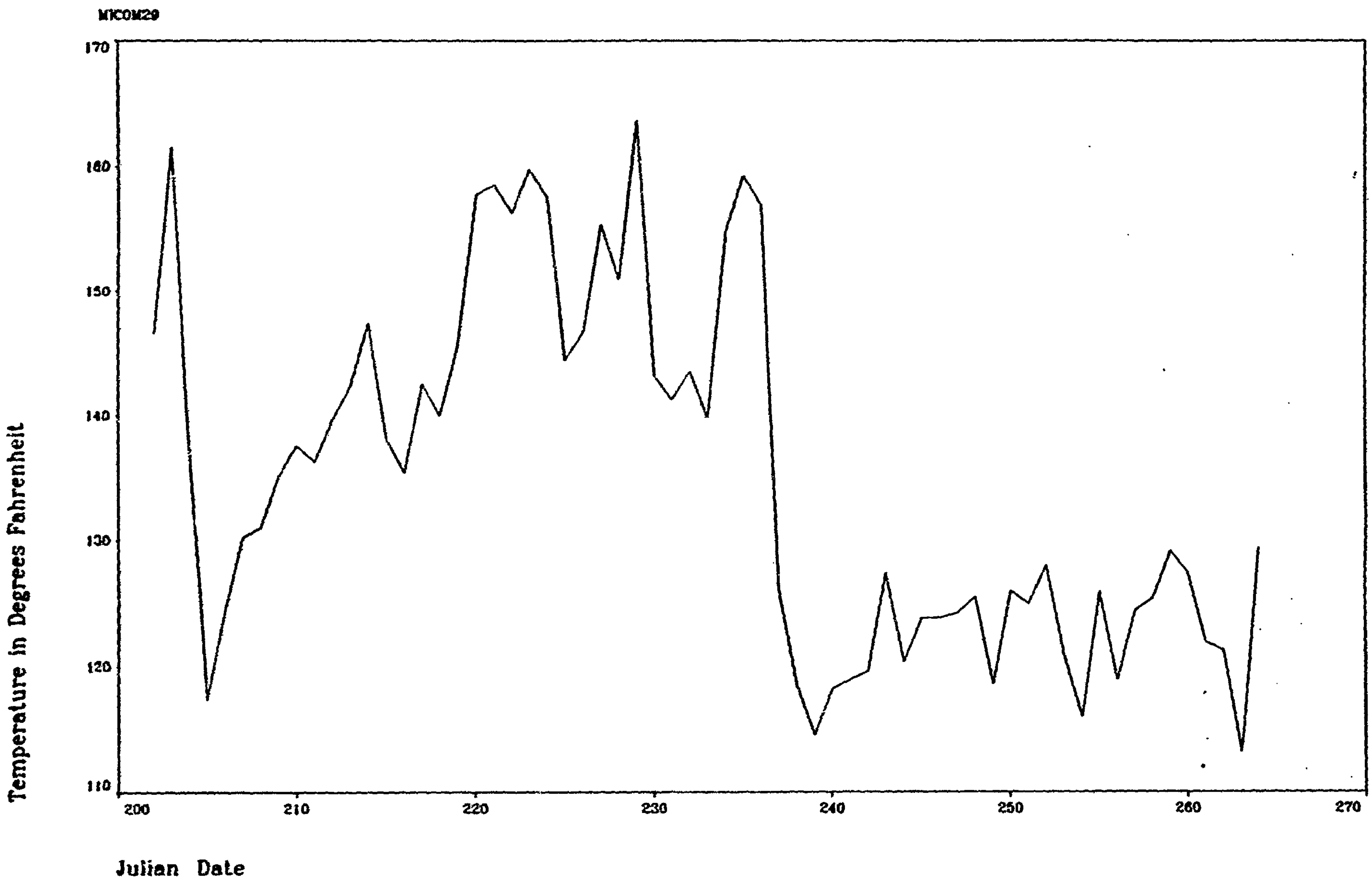
Peak Results from Kuwait Stinger Temperature Monitoring
Date: July 20 - Sept 20, 1992

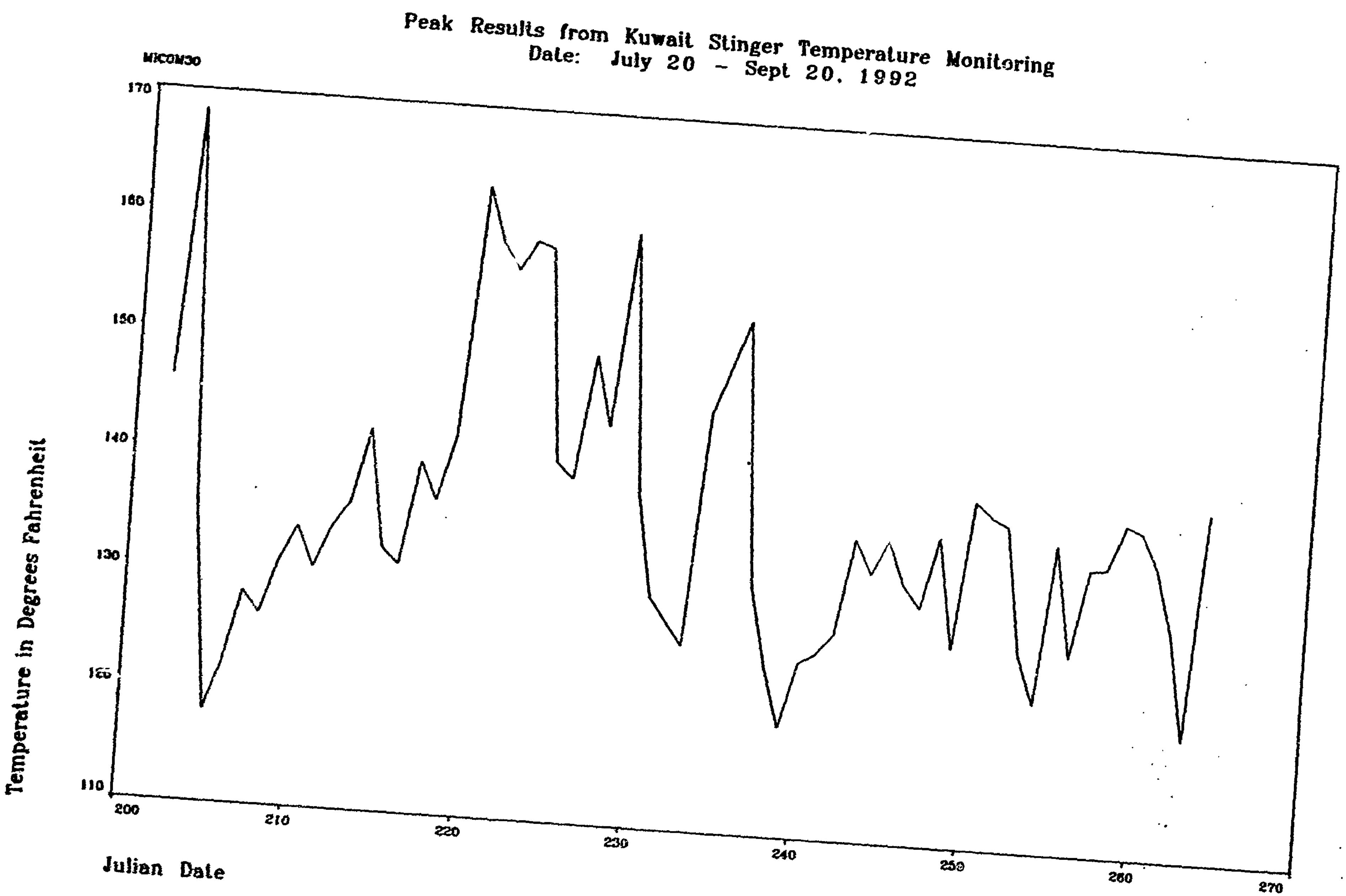




Peak Results from Kuwait Stinger Temperature Monitoring
Date: July 20 - Sept 20, 1992
MICOM28
160
150
140
130
120
110
Temperature in Degrees Fahrenheit
200
210
220
230
240
250
260
270
Julian Date

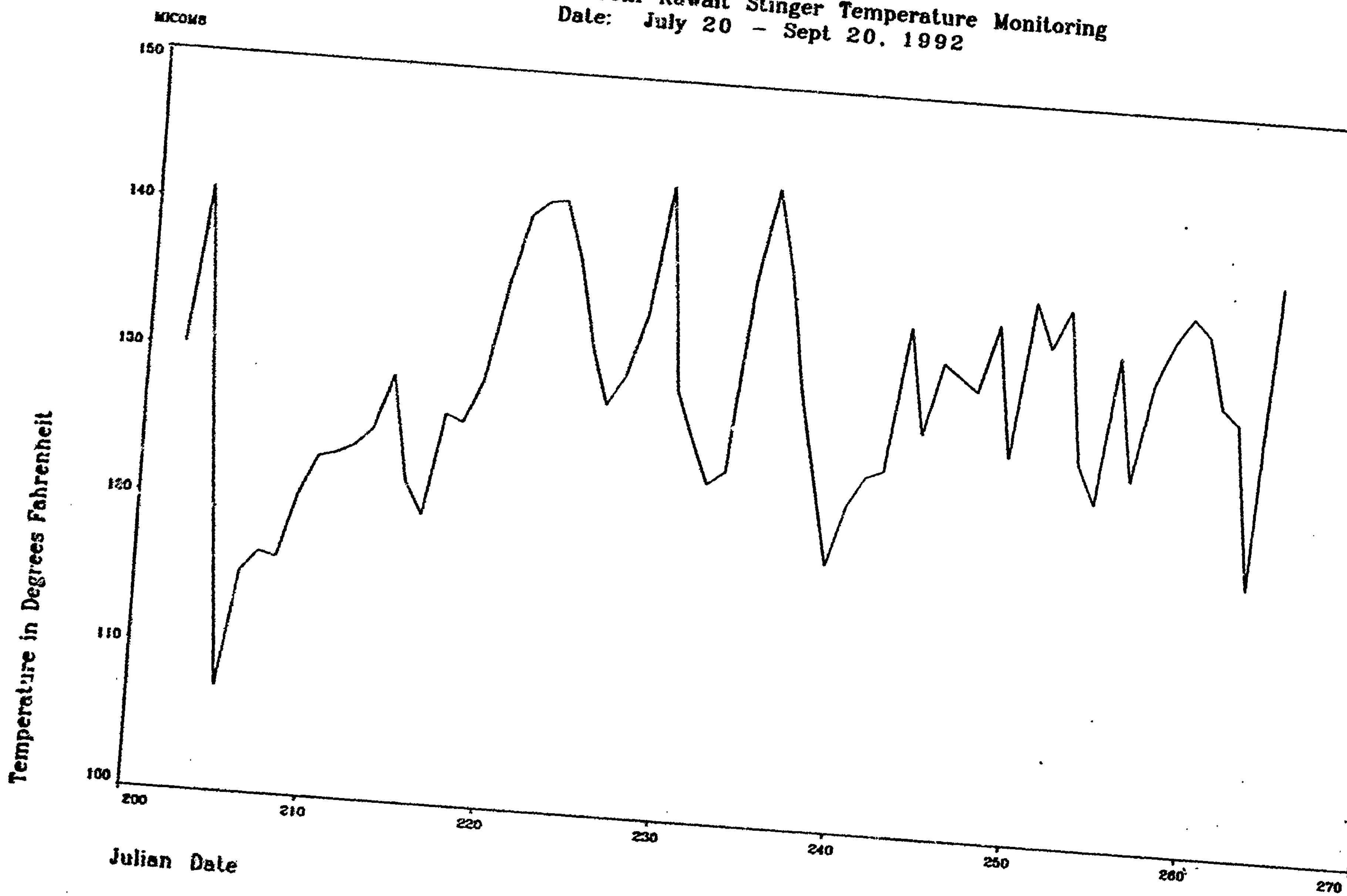
Peak Results from Kuwait Stinger Temperature Monitoring
Date: July 20 - Sept 20, 1992



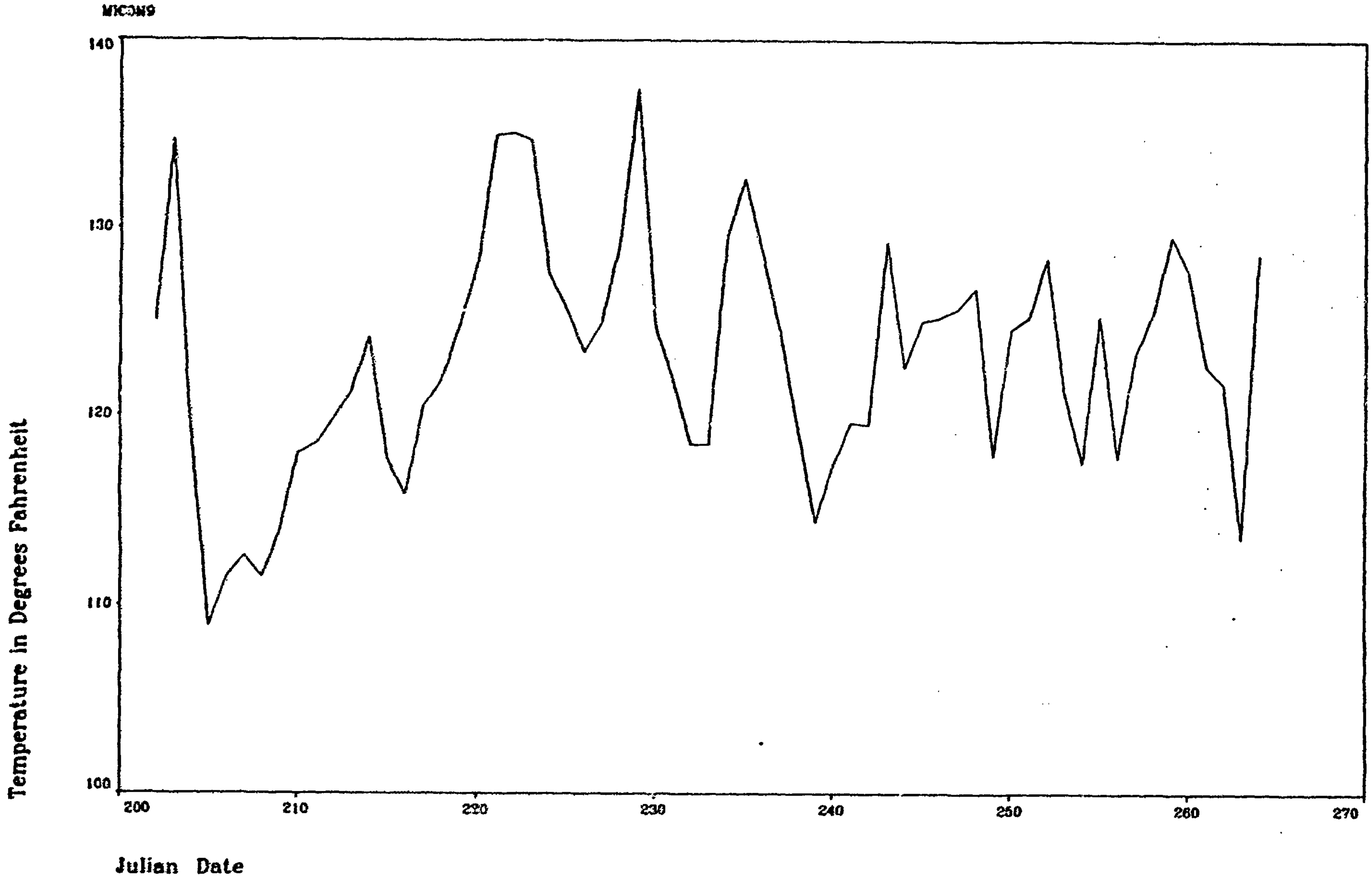


Peak Results from Kuwait Stinger Temperature Monitoring
Date: July 20 - Sept 20, 1992
MICOM30
170
160
150
140
130
120
110
200
210
220
230
240
250
260
270
Temperature in Degrees Fahrenheit
Julian Date

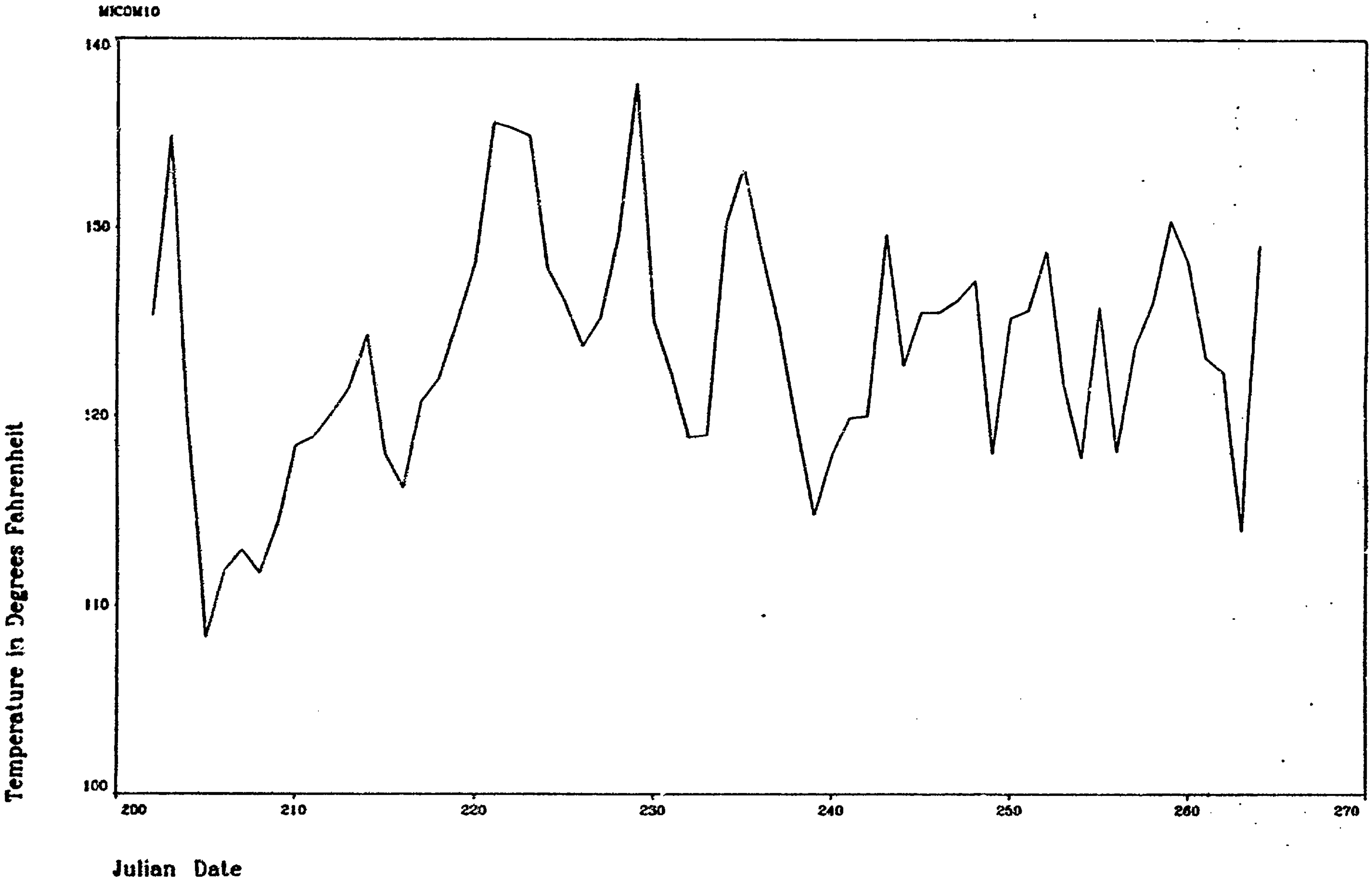
Peak Results from Kuwait Stinger Temperature Monitoring
Date: July 20 - Sept 20, 1992



Peak Results from Kuwait Stinger Temperature Monitoring
Date: July 20 - Sept 20, 1992



Peak Results from Kuwait Stinger Temperature Monitoring
Date: July 20 – Sept 20, 1992



PART 7

ENVIRONMENTAL DATA

Note: Probe locations found in Part 3.

Table 2

Peak Ambient Conditions from Kuwait

Julian Date	Wind Speed (MPH)	Ambient Temperature (Fahrenheit)	Ambient Humidity (Percent)	Solar Radiation (BTU/hr/ft^2)
202	56.79	113.80	28.31	272.32
203	67.54	117.30	33.20	258.83
204	110.00	111.20	32.28	265.24
205	134.60	104.00	33.99	227.64
206	120.30	106.10	34.48	232.06
207	103.60	107.50	32.99	237.37
208	110.20	107.30	32.25	241.79
209	91.20	108.80	31.36	240.47
210	90.50	110.70	32.58	242.90
211	93.90	111.50	31.90	238.92
212	78.90	111.30	32.98	249.31
213	72.20	111.50	32.67	254.85
214	67.76	111.00	29.36	246.88
215	111.10	111.20	29.60	257.72
216	111.70	108.90	29.09	252.19
217	77.80	110.70	27.17	245.78
218	72.70	111.80	28.77	242.90
219	59.35	111.80	29.53	244.23
220	53.84	110.60	42.32	242.01
221	56.52	115.70	55.86	248.21
222	48.74	116.90	45.19	241.35
223	58.19	116.80	59.09	251.53
224	67.58	113.60	72.90	231.84
225	63.94	113.90	59.67	230.29
226	67.75	112.10	37.17	251.75
227	71.20	114.00	30.13	247.77
228	59.66	116.70	35.44	253.30
229	37.61	119.90	41.19	239.58
230	94.80	117.00	34.61	249.76
231	90.90	113.40	33.30	251.08
232	83.60	110.30	30.91	250.64

Julian Date	Wind Speed (MPH)	Ambient Temperature (Fahrenheit)	Ambient Humidity (Percent)	Solar Radiation (BTU/hr/ft^2)
233	57.05	108.40	35.81	219.01
234	33.34	113.00	33.23	215.69
235	56.13	115.60	41.78	226.75
236	61.40	115.20	50.68	229.18
237	92.50	116.20	42.43	233.17
238	104.90	111.60	39.15	238.70
239	129.30	108.90	39.58	246.22
240	111.00	110.80	37.69	234.94
241	93.40	110.60	32.16	226.97
242	69.12	109.10	34.70	223.43
243	57.64	109.80	49.33	216.35
244	54.06	106.20	62.64	207.50
245	55.32	109.50	63.24	207.06
246	67.96	112.90	37.79	215.47
247	61.01	112.50	34.66	219.67
248	54.06	110.00	92.00	213.92
249	55.14	103.90	89.10	205.96
250	62.58	108.40	77.70	217.02
251	41.15	111.80	85.70	205.29
252	49.55	112.70	27.46	213.48
253	73.80	112.00	37.14	212.59
254	75.00	109.40	37.52	216.35
255	49.60	108.40	67.96	218.79
256	59.85	106.10	73.80	210.60
257	53.44	107.60	82.90	225.42
258	46.48	111.30	60.52	206.84
259	43.74	114.40	48.97	204.63
260	60.58	112.70	41.86	207.06
261	59.08	108.30	86.30	197.33
262	43.62	108.70	77.30	194.67
263	86.60	104.50	40.93	211.49
264	40.89	109.90	42.46	198.88
	72.12	111.23	45.14	231.13

Table 3

Peak Daily Temperatures
Inside the MILVAN

Julian Date	Top STINGER Case/MILVAN	Inside STINGER Case/MILVAN	MICOM Probe #1
237	131.72	129.57	130.70
238	123.50	122.53	124.70
239	117.87	116.97	118.70
240	122.53	120.63	123.00
241	123.50	121.57	125.10
242	125.47	121.57	125.70
243	143.58	132.82	136.10
244	139.80	128.53	128.40
245	138.58	128.53	133.20
246	128.53	130.64	132.40
247	123.50	127.49	131.80
248	136.22	130.64	136.20
249	127.49	121.57	127.40
250	136.22	132.82	137.80
251	141.04	131.72	135.00
252	142.30	133.93	137.90
253	118.78	123.50	127.10
254	115.20	120.63	123.80
255	137.39	132.82	135.00
256	126.47	124.47	126.30
257	135.07	130.64	133.30
258	132.82	130.64	136.40
259	130.64	133.93	138.90
260	127.49	131.72	137.00
261	138.58	129.57	131.60
262	131.72	126.47	130.40
263	110.10	115.20	119.00
264	141.04	132.82	140.70
	130.18	126.74	130.18
		229	144.90

Table 4

Peak Daily Temperatures
Inside the MILVAN

Julian Date	MICOM Probe #2	MICOM Probe #3	MICOM Probe #4	MICOM Probe #19	MICOM Probe #6
202	131.10	130.70	130.60	132.50	130.70
203	142.30	141.70	141.30	144.40	141.40
204	124.80	124.50	124.40	126.30	124.30
205	107.30	107.30	107.30	113.10	109.90
205	115.80	115.60	115.50	116.70	115.40
206	117.10	116.90	116.90	118.30	116.70
207	116.50	116.40	116.40	117.80	116.10
208	120.80	120.80	120.80	123.10	120.50
209	123.80	123.50	123.40	125.10	123.30
210	124.10	123.70	123.60	125.40	123.60
211	124.90	124.50	124.30	126.50	124.40
212	126.20	125.80	125.80	127.60	125.80
213	129.90	129.50	129.40	132.50	129.40
214	122.30	122.20	122.30	124.50	121.90
215	120.40	120.10	120.00	123.50	119.90
216	127.40	127.00	126.80	128.50	126.90
217	126.90	126.60	126.60	129.20	126.50
218	130.10	129.50	129.60	133.00	129.50
219	136.90	136.40	136.40	139.90	136.10
220	142.70	141.50	140.40	142.10	141.40
221	143.00	142.20	141.80	142.70	142.20
222	143.10	142.40	142.10	143.80	142.30
223	138.60	138.50	138.70	141.70	138.00
224	132.60	132.20	132.10	133.90	132.20
225	128.70	128.40	128.50	130.40	128.40
226	130.90	130.50	130.60	133.40	130.50
227	135.10	134.50	134.60	137.00	134.60
228	144.90	144.10	143.60	145.00	144.10
229	129.90	129.50	129.60	131.40	129.50
230	126.90	126.50	126.50	128.10	126.40
231	123.70	123.50	123.40	127.40	123.20

Julian Date	MICOM Probe #2	MICOM Probe #3	MICOM Probe #4	MICOM Probe #19	MICOM Probe #6
232	124.60	124.30	124.20	125.90	124.10
233	138.90	138.10	137.60	140.50	137.90
234	144.70	144.50	144.40	144.40	144.00
235	139.10	138.80	138.70	140.60	138.50
236	130.60	130.30	130.20	132.20	130.30
237	124.70	124.40	124.40	126.40	124.30
238	118.60	118.40	118.30	119.50	118.30
239	122.90	122.60	122.40	124.00	122.50
240	125.10	124.70	124.60	126.50	124.70
241	125.70	125.30	125.10	126.80	125.30
242	136.10	135.30	135.00	138.00	135.40
243	128.40	128.30	128.60	133.70	127.70
244	133.20	133.20	133.60	136.30	132.70
245	132.30	131.90	131.90	134.50	131.90
246	131.70	131.00	130.80	132.10	131.20
247	136.10	135.80	136.20	136.60	135.60
248	127.30	127.00	126.90	128.90	126.60
249	137.70	137.70	138.10	137.90	137.30
250	135.00	134.60	134.70	138.40	134.30
251	137.80	137.20	136.80	139.20	137.20
252	127.00	126.40	126.20	127.40	126.50
253	123.70	123.60	123.60	125.40	123.50
254	135.00	134.60	134.70	135.50	134.30
255	126.30	126.00	126.20	126.80	125.70
256	133.30	132.90	133.10	134.10	132.50
257	136.20	135.60	135.30	135.70	135.60
258	138.70	137.60	137.10	138.10	137.60
259	136.90	136.20	136.00	136.50	136.10
260	131.60	131.30	131.20	136.10	131.00
261	130.30	129.90	129.90	132.00	129.90
262	119.00	118.60	118.60	120.40	118.60
263	140.60	140.10	139.80	139.30	140.00
	130.12	129.73	129.64	131.66	129.62

Table 5

Peak Daily Temperatures
Inside the MILVAN

Julian Date	MICOM Probe #8	MICOM Probe #9	MICOM Probe #10
202	130.10	125.10	125.30
203	140.80	134.80	134.90
204	124.00	119.40	119.70
205	107.10	108.90	108.30
206	115.00	111.50	111.80
207	116.30	112.60	112.90
208	116.00	111.50	111.70
209	120.30	113.90	114.30
210	123.00	118.00	118.40
211	123.30	118.50	118.90
212	123.90	119.80	120.10
213	125.10	121.30	121.50
214	128.80	124.20	124.30
215	121.60	117.70	118.00
216	119.50	115.80	116.20
217	126.40	120.50	120.80
218	125.90	121.80	122.00
219	128.80	124.80	125.00
220	135.30	128.10	128.20
221	140.20	135.00	135.60
222	141.20	135.10	135.30
223	141.40	134.70	134.90
224	137.50	127.60	127.90
225	131.70	125.70	126.00
226	127.80	123.40	123.70
227	129.90	125.00	125.20
228	134.00	129.30	129.70
229	142.90	137.40	137.70
230	129.10	124.70	125.00
231	125.90	122.00	122.30
232	122.90	118.50	118.90

Julian Date	MICOM Probe #8	MICOM Probe #9	MICOM Probe #10
233	123.80	118.50	119.00
234	137.00	129.60	130.20
235	143.20	132.70	133.30
236	137.70	128.60	128.80
237	129.80	124.50	124.80
238	123.90	119.40	119.70
239	118.00	114.40	114.80
240	122.10	117.40	117.90
241	124.10	119.60	119.90
242	124.60	119.50	120.00
243	134.50	129.30	129.70
244	127.30	122.60	122.70
245	132.20	125.00	125.50
246	131.30	125.20	125.50
247	130.40	125.70	126.10
248	135.00	126.80	127.20
249	126.10	117.90	118.00
250	136.80	124.60	125.20
251	133.70	125.20	125.60
252	136.40	128.40	128.80
253	125.90	121.30	121.70
254	123.30	117.50	117.80
255	133.40	125.30	125.80
256	125.00	117.80	118.10
257	131.70	123.30	123.60
258	134.60	125.50	126.00
259	136.40	129.60	130.40
260	135.20	127.70	128.20
261	130.40	122.70	123.10
262	129.40	121.70	122.30
263	118.20	113.50	113.90
264	138.90	128.60	129.10
	128.98	123.11	123.45

Table 6

Peak Daily Temperatures
Inside the MILVAN

Julian Date	MICOM Probe #18	MICOM Probe #20	MICOM Probe #21	MICOM Probe #22	MICOM Probe #23
202	132.00	129.80	131.00	131.00	130.80
203	143.60	139.10	141.20	141.10	140.90
204	125.60	123.70	125.20	125.10	124.80
205	108.00	107.30	107.90	107.80	108.00
206	116.40	115.30	116.20	116.10	115.90
207	118.00	116.70	117.70	117.60	117.50
208	117.30	116.20	117.50	117.30	117.20
209	122.70	120.60	122.20	122.10	121.90
210	124.40	122.80	124.30	124.30	125.30
211	125.00	123.10	124.30	124.30	124.00
212	125.70	123.90	125.00	125.00	124.70
213	127.40	125.40	126.30	126.30	126.00
214	131.60	128.70	130.10	130.10	129.90
215	123.90	121.70	123.20	123.10	128.20
216	122.70	119.90	120.40	120.40	123.40
217	128.00	126.00	127.10	127.10	126.70
218	128.60	126.20	127.40	127.40	127.10
219	132.20	129.20	130.50	130.50	130.10
220	138.10	133.40	135.30	135.40	134.80
221	141.50	137.80	138.90	138.90	138.80
222	142.50	138.70	141.00	141.00	140.00
223	142.60	137.70	141.50	141.40	140.50
224	141.00	138.00	139.60	139.60	139.50
225	133.70	131.50	132.60	132.60	132.30
226	130.20	127.90	128.90	128.90	128.50
227	133.30	130.00	131.50	131.50	131.20
228	136.50	133.90	135.10	135.10	134.80
229	144.70	142.00	143.30	143.30	143.10
230	131.40	129.30	130.50	130.40	131.30
231	128.00	125.90	127.00	127.00	126.70
232	126.70	124.10	124.80	124.80	124.70

Julian Date	MICOM Probe #18	MICOM Probe #20	MICOM Probe #21	MICOM Probe #22	MICOM Probe #23
233	125.90	124.10	125.20	125.10	125.10
234	140.30	137.50	138.10	138.00	137.60
235	144.50	141.70	144.50	144.40	143.70
236	139.90	137.20	139.60	139.60	139.40
237	132.10	129.90	131.10	131.10	130.80
238	126.40	124.20	125.20	125.20	125.00
239	119.10	117.80	119.00	118.90	118.70
240	123.90	122.20	123.40	123.30	123.10
241	126.40	124.20	125.40	125.30	125.20
242	126.80	124.70	125.60	125.60	125.20
243	138.00	134.50	135.40	135.30	135.10
244	133.00	128.50	129.20	129.20	129.20
245	136.30	133.20	134.40	134.30	134.20
246	134.50	132.10	132.90	132.80	132.50
247	131.80	129.50	131.00	131.00	130.60
248	136.80	135.10	137.00	137.00	136.70
249	128.70	124.60	126.70	126.60	126.20
250	138.20	136.30	139.00	139.00	138.50
251	138.20	134.20	135.20	135.10	135.20
252	139.70	135.60	136.90	136.90	136.30
253	127.50	125.90	126.80	126.80	126.40
254	125.40	123.40	124.70	124.60	124.30
255	136.30	134.00	134.80	134.80	134.30
256	127.20	125.20	126.20	126.20	125.80
257	134.50	131.80	133.30	133.20	132.70
258	136.10	132.90	135.50	135.40	134.60
259	138.30	135.40	138.10	138.00	137.50
260	136.20	135.00	136.60	136.60	136.30
261	135.90	132.60	132.00	132.00	131.90
262	132.30	129.40	130.50	130.40	129.90
263	120.30	118.60	119.50	119.40	119.10
264	139.60	136.00	139.80	139.70	138.80
	131.32	128.78	130.16	130.12	129.98

Table 7

Peak Daily Temperatures
Outside the MILVAN
No Shipping Container

Julian Date	MICOM Probe #13	MICOM Probe #14	MICOM Probe #15	MICOM Probe #16	MICOM Probe #17
202	129.80	137.30	132.90	131.80	130.60
203	142.00	151.00	146.90	145.90	145.00
204	125.60	129.10	125.80	125.60	125.40
205	107.60	110.70	107.90	107.90	107.30
206	116.60	116.30	114.90	114.80	114.70
207	119.10	122.50	117.70	117.30	117.00
208	118.30	121.20	116.70	116.40	115.70
209	122.00	124.40	122.20	122.00	121.50
210	124.90	129.50	126.50	126.10	125.40
211	124.30	128.10	124.80	124.30	123.50
212	127.00	131.50	126.90	126.40	125.50
213	128.20	133.70	128.00	127.50	126.70
214	129.70	137.80	134.10	132.70	130.90
215	124.90	132.30	126.50	125.80	124.90
216	122.00	127.60	121.90	122.30	121.20
217	126.80	129.10	126.00	125.90	126.90
218	127.10	133.50	129.70	129.00	128.00
219	129.90	136.80	133.40	132.50	131.40
220	135.00	151.30	145.00	143.80	142.10
221	137.20	150.60	142.50	141.40	139.70
222	136.40	150.70	142.10	140.40	138.70
223	138.80	154.10	143.70	142.20	139.60
224	135.30	148.70	137.10	136.30	136.10
225	130.30	138.30	129.00	128.30	127.60
226	128.50	134.80	128.20	127.40	127.00
227	132.20	140.80	132.40	131.70	130.40
228	133.50	137.00	131.40	131.00	130.50
229	140.10	149.20	141.40	140.60	139.30
230	129.30	132.60	129.10	128.80	128.20
231	126.70	131.80	126.40	125.80	125.60

Julian Date	MICOM Probe #13	MICOM Probe #14	MICOM Probe #15	MICOM Probe #16	MICOM Probe #17
232	125.40	129.90	126.20	125.50	125.40
233	122.80	126.40	123.90	123.20	122.50
234	134.40	140.40	136.50	135.50	134.50
235	140.30	147.50	139.70	138.60	138.50
236	136.80	148.00	139.40	138.20	135.00
	128.60	133.30	130.00	129.40	128.50

Table 8

Peak Daily Temperatures
Outside the Milvan
No Shipping Container

Julian Date	MICOM Probe #24	MICOM Probe #25	MICOM Probe #26	MICOM Probe #27	MICOM Probe #28
202	127.50	126.30	123.90	135.00	136.10
203	141.20	139.80	137.10	150.50	151.80
204	122.10	121.10	119.50	129.90	130.80
205	108.60	107.90	107.40	111.10	111.80
206	114.30	113.80	112.70	119.20	119.70
207	115.90	115.20	113.80	122.50	123.50
208	115.30	114.60	113.30	123.90	124.90
209	119.30	118.30	116.30	126.40	127.50
210	121.70	120.70	118.50	129.40	130.90
211	121.70	120.50	118.40	129.60	130.60
212	123.00	121.70	119.40	132.50	133.60
213	124.20	122.90	120.70	134.20	135.30
214	126.20	125.00	122.30	137.60	139.60
215	121.30	120.10	118.50	130.90	132.00
216	118.90	117.60	115.70	126.50	127.70
217	124.40	124.00	122.90	131.40	132.40
218	124.70	123.00	120.80	132.70	134.30
219	127.50	125.60	122.80	136.50	138.70
220	137.00	135.10	132.40	145.60	148.00
221	135.10	133.60	131.60	147.20	148.90
222	133.70	132.40	130.70	145.90	147.80
223	137.10	136.30	135.30	148.40	151.20
224	133.00	131.50	129.60	144.90	146.20
225	125.80	124.60	124.20	136.50	137.50
226	124.90	124.10	122.70	135.90	137.70
227	126.60	125.80	124.10	140.40	142.80
228	129.80	129.20	128.80	140.40	141.40
229	137.60	136.30	135.20	149.80	151.90
230	126.40	125.50	124.30	133.80	135.10
231	123.20	122.40	120.90	132.60	134.10

Julian Date	MICOM Probe #24	MICOM Probe #25	MICOM Probe #26	MICOM Probe #27	MICOM Probe #28
232	122.40	121.60	119.90	132.50	134.60
233	120.00	118.70	116.70	129.90	131.70
234	133.30	131.60	128.60	144.20	145.80
235	138.50	136.30	133.20	148.60	149.00
236	131.70	130.00	127.50	144.90	147.00
	126.00	124.80	123.00	135.30	136.70

Table 9

Peak Daily Temperatures
Outside the Milvan
In Shipping Container

Julian Date	MICOM Probe #13	MICOM Probe #14	MICOM Probe #15	MICOM Probe #16	MICOM Probe #17
237	129.80	129.20	131.10	131.20	131.00
238	123.10	122.60	124.40	124.40	124.40
239	118.30	117.90	119.40	119.40	119.30
240	122.10	121.60	124.90	125.00	124.90
241	123.40	122.70	125.60	125.70	125.70
242	123.90	123.00	127.40	127.40	127.40
243	133.60	132.00	135.40	135.50	135.50
244	131.90	130.90	132.40	132.40	132.50
245	131.60	130.70	135.50	135.60	135.60
246	131.00	130.10	131.90	132.10	132.10
247	128.90	127.80	130.30	130.50	130.40
248	132.00	130.10	135.90	136.10	136.20
249	125.00	124.80	126.80	126.90	126.70
250	135.30	132.60	139.40	139.60	139.30
251	134.00	131.90	137.70	137.70	137.90
252	134.60	133.30	137.20	137.10	137.30
253	125.20	125.00	126.60	126.80	126.70
254	121.10	120.40	122.70	122.80	122.70
255	133.80	131.90	136.20	136.40	136.10
256	126.60	125.90	126.90	127.10	126.90
257	132.10	131.00	134.40	134.50	134.20
258	131.10	130.10	134.70	134.90	134.30
259	133.30	132.00	138.20	138.40	138.20
260	132.80	131.90	137.50	137.70	137.50
261	132.00	130.90	134.10	134.10	134.40
262	127.40	126.50	129.30	129.50	129.30
263	119.80	119.60	120.10	119.90	120.00
264	135.90	134.50	140.00	140.30	139.70
	127.40	126.50	129.80	129.90	129.80

Table 10

Peak Daily Temperatures
Outside the Milvan
In Shipping Container

Julian Date	MICOM Probe #24	MICOM Probe #25	MICOM Probe #26	MICOM Probe #27	MICOM Probe #28
237	128.60	128.40	128.30	126.60	126.50
238	122.30	122.10	122.00	119.00	118.90
239	118.30	118.20	118.10	115.00	114.90
240	122.60	122.30	122.20	118.70	118.60
241	123.10	122.80	122.60	119.60	119.40
242	125.30	124.90	124.60	120.20	120.10
243	132.60	132.10	131.90	128.70	128.30
244	131.60	131.00	130.70	121.10	121.00
245	132.40	131.60	131.20	124.80	124.60
246	128.70	128.30	128.20	124.40	124.30
247	127.20	127.00	126.80	125.00	124.90
248	131.80	130.90	130.40	126.50	126.40
249	125.20	124.80	124.60	119.10	118.90
250	135.10	133.90	133.20	126.50	126.50
251	134.70	133.80	133.10	125.80	125.70
252	133.70	133.00	132.50	128.70	128.70
253	124.70	124.50	124.20	121.50	121.40
254	119.60	119.20	119.00	116.60	116.50
255	132.10	131.30	130.80	127.00	126.80
256	123.60	123.00	122.80	119.60	119.50
257	130.00	129.00	128.50	125.30	125.30
258	130.00	129.30	128.80	126.10	126.00
259	133.20	132.50	132.10	130.10	129.90
260	133.40	132.30	131.80	128.40	128.30
261	132.10	131.40	131.10	122.70	122.60
262	125.50	125.00	124.60	122.00	121.90
263	119.00	118.70	118.40	113.80	113.70
264	134.00	133.70	133.30	130.20	130.10
	126.80	126.30	126.00	122.50	122.30

Table 11

Peak Daily Temperatures
Outside the Milvan
No Shipping Container

Julian Date	MICOM Probe #29	MICOM Probe #30
202	146.60	145.90
203	161.60	168.30
204	137.80	134.60
205	117.40	117.80
206	124.60	122.00
207	130.20	128.00
208	131.00	126.10
209	135.10	130.70
210	137.60	133.70
211	136.30	130.30
212	139.70	133.90
213	142.30	135.90
214	147.50	142.30
215	138.20	132.30
216	135.40	131.00
217	142.60	139.80
218	140.00	136.60
219	145.60	142.10
220	157.70	163.30
221	158.50	158.70
222	156.30	156.50
223	159.80	159.00
224	157.50	158.50
225	144.50	140.50
226	146.70	139.10
227	155.40	149.70
228	151.00	143.70
229	163.70	160.20
230	143.20	138.20
231	141.30	129.60

Julian Date	MICOM Probe #29	MICOM Probe #30
232	143.60	127.60
233	139.80	125.60
234	154.90	145.40
235	159.30	149.40
236	156.90	153.40
	144.90	140.70

Table 12

Peak Daily Temperatures
Outside the MILVAN
In Shipping Container

Julian Date	MICOM Probe #29	MICOM Probe #30
237	126.00	130.90
238	118.50	124.30
239	114.60	119.30
240	118.20	124.80
241	118.90	125.60
242	119.60	127.40
243	127.40	135.50
244	120.30	132.70
245	123.80	135.60
246	123.80	131.90
247	124.20	130.10
248	125.50	136.10
249	118.60	126.80
250	126.00	139.40
251	125.00	138.10
252	128.00	137.40
253	120.80	126.60
254	116.00	122.60
255	125.90	136.10
256	118.90	126.70
257	124.40	134.10
258	125.40	134.30
259	129.10	138.10
260	127.40	137.50
261	121.90	134.60
262	121.20	129.30
263	113.20	120.30
264	129.40	139.60
	121.70	129.80

PART 8

APPENDIX

PART 8-A

PRELIMINARY TEST INFORMATION

Del.

DEPARTMENT OF THE ARMY
PROGRAM EXECUTIVE OFFICE, AIR DEFENSE
REDSTONE ARSENAL, ALABAMA 35898 - 5750

REPLY TO
ATTENTION OF

SFAE-MSL-ATA-SE 26 Aug 92

MEMORANDUM FOR Director, U.S. Army defense Ammunition Center and School, ATTN: SMCAC-DEV (Mr. Bill Meyer) Savanna, IL 61074-9639

SUBJECT: Kuwait STINGER Heating Test Data Request

1. It is requested that eleven data plots as described on the page 2 be generated for the day of each week on which the highest launch motor grain temperature (MICOM Channel 27) occurred. Please convert Langleys per minute to BTU/hr-ft2, (Langleys/min x 3.687 x 60).

2. Location and identification of the MICOM data channels are shown on page 3.

3. It is also requested that floppy discs with the Kuwait data and Saudi Arabia weather station data from August 1990 through October 1991 be sent to the following address:

Mr. Frank Frederick
Mail Zone 601-28
Hughes Missile Systems Company
Pomona Facility
P.O. Box 2507
Pomona, CA 91769-2507

4. Weather station data for Saudi Arabia should include Dry Bulb Temperature, Relative Humidity, Solar Radiation, and Wind Speed and Direction.

5. Point of contact is Richard Cox, DSN 746-4173.

Julian L. Cothran
JULIAN L. COTHRAN
Chief, Systems Engineering Division
ATAM Project Office

DATA PLOTS FOR STINGER TEMPERATURE TEST IN KUWAIT

1. AMB TEMP, SOLAR RADIATION, WIND VEL, SKIN TEMP (Top of Milvan)

2. AMB TEMP, SKIN TEMP (Top of Milvan), MICOM Channels 18, 19 and 20 (18 - Air Temp inside Weapon Round Container, 19 - Top of Weapon Round Container, 20 - Bottom of Weapon Round Container)

3. AMB TEMP, SOLAR RADIATION, TEMP OF EMPTY CONTAINER (Top Skin, Inside Air, Bottom Skin)

4. AMB TEMP, MICOM Channels 1, 2, 3, 4 (1 & 2 - Grain Temp at 12 'clock Position, 3 - O.D. of Launch Motor Case over #1 & 2, and 4 - O.D. of Launch Tube over #3)

5. AMB TEMP, MICOM Channels 6, 8, (6 - Boost Grain at Insulation Interface, 8 - O.D. of Launch Tube over #6

6. AMB TEMP, MICOM Channels 9, 10, 11 (9 - Sustain Grain at Insulation Interface, 10 - O.D. of Flight Motor Case over #9, 11 - O.D. of Launch Tube over #10)

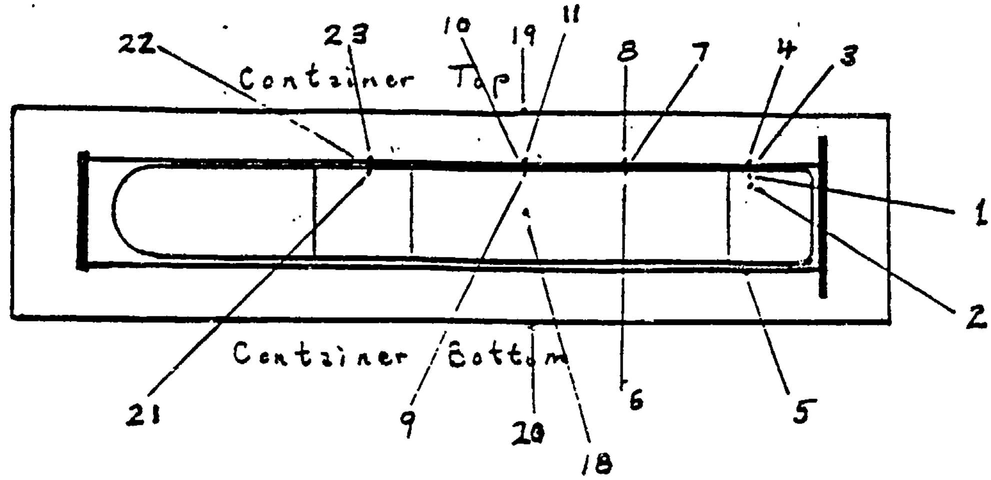
7. AMB TEMP, MICOM Channels 21, 22, 23 (21 - Warhead Charge At I.D. of Case, 22 - O.D. of Warhead Case over #21, 23 - O.D. of Launch Tube over # 22)

8. AMB TEMP, SOLAR RADIATION, MICOM Channels 16, 17, 15, 30 (16 & 17 - Launch Motor Grain Temp at 12 'clock Position, 15 - O.D. of Launch Motor Case at 12 'clock, 30 - O.D. of Launch Tube over #15)

9. AMB TEMP, SOLAR RADIATION, MICOM Channels 24, 25, 26 (24 - Boost Grain at Insulation Interface, 25 - O.D. of Flight Motor Case over #24, 26 - O.D. of Launch Tube over #25)

10. AMB TEMP, SOLAR RADIATION, MICOM Channels 27, 28, 29 (27 - Sustain Grain at Insulation, 28 - O.D. of Flight Motor Case over #27, 29 - O.D. of Launch Tube over #28)

11. AMB TEMP, SOLAR RADIATION, MICOM Channels 13, 14 (13 - O.D. of Warhead Case, 14 - O.D. of Launch Tube over #13)



THERMOCOUPLE NO.		THERMOCOUPLE LOCATION
INSIDE MILVAN	OUTSIDE MILVAN	
1	16	0.010 " in 1 'clock position of 12 'clock stick on outside row
2	17	0.010" in 12 'clock position of 12:03 'clock stick on second row
3	15	O.D. of LM case over #1 (#16)
4	30	O.D. of LT over #3 (#15)
5	31	O.D. of LT 180 degrees from #4 (#30)
6	24	Boost propellant/insulation interface
7*	25	O.D. of FM case over #6 (#24)
8	26	O.D. of LT over #7 (#25)
9	27	Sustain propellant/insulation interface
10	28	O.D. of FM case over #9 (#27)
11	29	O.D. of LT over #10 (#28)
21	12*	0.020" from Warhead case I.D. in wax
22	13	O.D. of Warhead case over #21 (#12)
23	14	O.D. of LT over #22 (#13)
18	Air temp inside weapon round container in Milvan	
19	Top of Weapon Round Container in Milvan	
20	Bottom of Weapon Round Container in Milvan	

* No data received because of instrumentation malfunction.

NOTE: From July 18 through August 23, the missile round outside the Milvan was lying on the ground directly exposed to solar radiation. On August 24 this round was placed in a weapon round container which was exposed to solar radiation.

DEPARTMENT OF THE ARMY
PROGRAM EXECUTIVE OFFICE, AIR DEFENSE
REDSTONE ARSENAL, ALABAMA 35898-5790

REPLY TO
ATTENTION OF

SFAE-MSL-ATA-SE 20 Aug 92

MEMORANDUM FOR Director, U.S. Army Defense Ammunition Center and School, ATTN: SMCAC-DEV (Mr. J. Krohn) Savanna, IL 61074-9639

SUBJECT: Change of Instrumented STINGER Round Outside of Milvan in Kuwait ASP

1. Data received to date from Kuwait are encouraging with respect to missile response to the ambient conditions. The bare round has been exposed to quite high radiation and ambient temperatures for four weeks. This data is considered adequate as a data base for the bare round condition. Since there are a few weeks of high heating conditions remaining this year uncovered open storage of a STINGER round in a metal container could be evaluated using the empty container and the bare round.

2. It is requested that the instrumented bare STINGER round presently lying on the ground near the weather station be placed in the metal shipping container.

3. To accomplish this without disturbing the missile instrumentation cable connections an opening should be cut in the metal container at the sealing edge near the right latch (Launch Motor end). The cut edge of the container should be smooth and the cable bundle should be protected in this area. After the container top is closed the cable penetration should be sealed with silicone as well as possible.

4. The following container temperatures should be recorded as well as those for the missile/launch tube; Container Top, Container Bottom, and Interior Air.

5. Point of contact is Richard Cox, DSN 746-4173.

for Billy Kerley
Craig Combs
Chief, Missile Branch
ATAM Project Office

DEPARTMENT OF THE ARMY
PROGRAM EXECUTIVE OFFICE, AIR DEFENSE
REDSTONE ARSENAL, ALABAMA 35898-5750

REPLY TO
ATTENTION OF

SFAE-AD-ATA-SE

0 2 JUL ...

MEMORANDUM FOR Director, U.S. Army Defense Ammunition Center
and School, ATTN: SMCAC-DEV (Mr. J. Krohon)
Savanna, IL 61074-9639

SUBJECT: Support Requested for STINGER Temperature Monitoring Test in Kuwait

1. Reference letter, AMCAC-DEV, 24 Jun 92, subject: STINGER Missile Temperature Monitoring in Kuwait (enclosed).

2. Per discussions between Messrs. Richard Cox, U.S. Army Missile Command (MICOM) and Jerry Krohn/Bill Meyer, U.S. Army Defense Ammunition Center and School (USADACS), assistance is requested in recording weather and missile temperature data in Kuwait beginning in Jul 92.

3. The proposed test plan included in reference memorandum is adequate as written. The MICOM will instrument and deliver two inert STINGER rounds with E type thermocouple leads extending from the test rounds. We will also provide extension cables for each measurement.

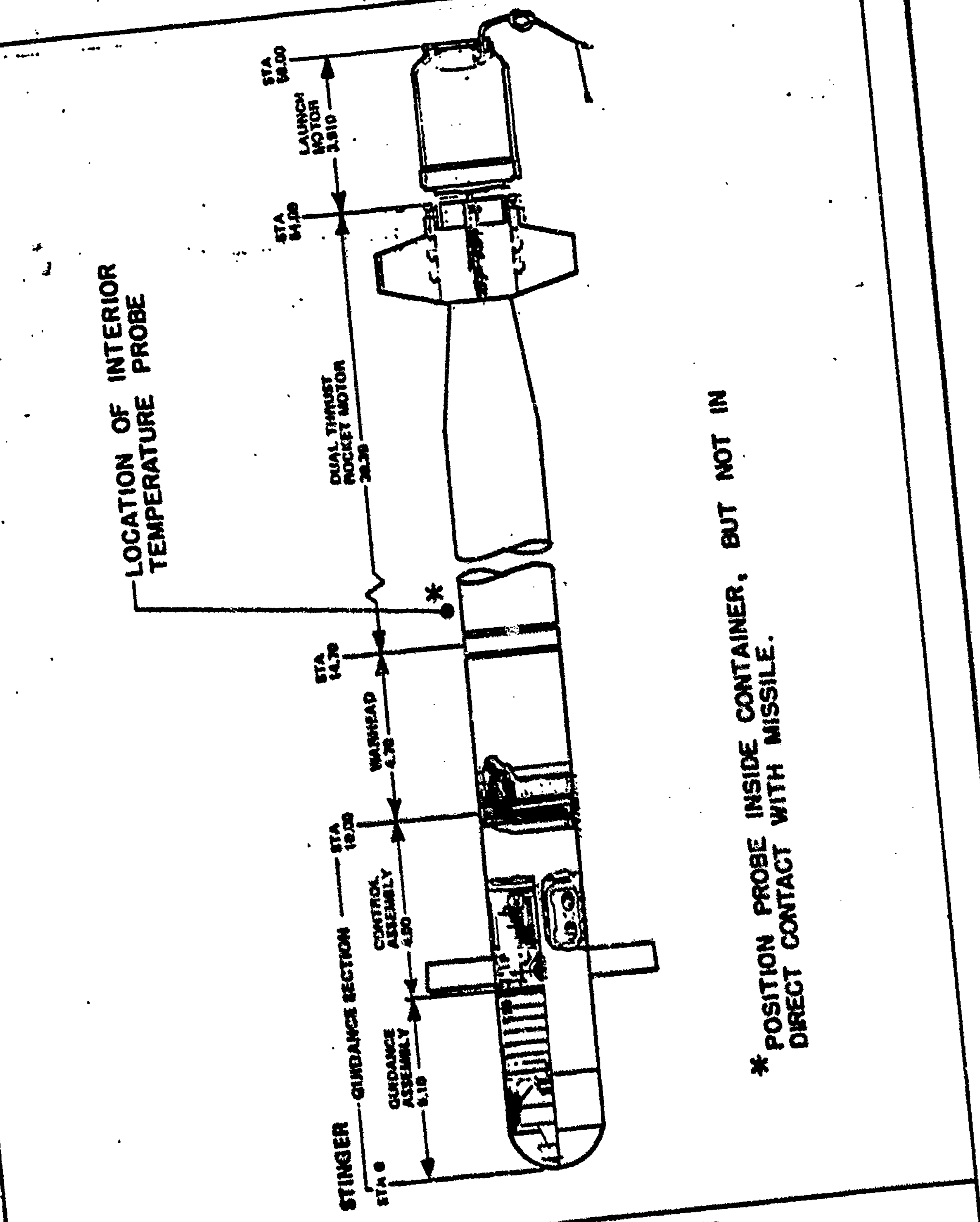
4. There will be $20K forwarded to cover costs incurred by USADACS in this effort.

5. Point of contact is Richard Cox, DSN 746-4273 or commercial 205-876-4173.

Julian L. Cothran

Encl

JULIAN L. COTHRAN
Chief, System Engineering Division
Air-to-Air Missile/AVENGER Project
Office



DRAFTSMAN TRS	TITLE **STINGER MISSILE**
TEST ENGINEER	U.S. ARMY DEFENSE AMMUNITION CENTER AND SCHOOL, SAVANNA, ILLINOIS 61074-9639
CHIEF, VALIDATION ENGINEERING DIVISION	

PART 8-B

MICOM FINAL TEST REPORT

HUGHES
Missile Systems Company

TECHNICAL DESIGN INFORMATION

TDI	41-3-75.90-1
MODEL	STINGER

DATE: 14 December 1992

TO: P. L. Boettcher

FROM: Dynamic Analysis

SUBJECT: Stinger Launch Motor Temperature Correlations in Desert Environments

REFERENCE: Boettcher, P.L., "Kuwait and Saudi Arabia Diurnal Cycle Data Summary", TM41-3-75.89-1, 7 December 1992

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INTRODUCTION AND SUMMARY

A thermal study was performed to correlate test data taken on a Stinger missile in the Kuwaiti desert so that predictions of launch motor temperatures could be made using the diurnal environments measured in Saudi Arabia during Operation Desert Storm. This was done because of a concern that a component of the launch motors (the adiprene potting material) may have exceeded its operational limit of 165°F. Chemical breakdown of the material above this temperature could result in a case rupture when the motor is subsequently fired at any operational temperature.

After satisfactorily correlating measured data, application of the Saudi environmental conditions (solar flux, air temperature and wind speed) to the tailored thermal model showed that the adiprene remained below a temperature of 155°F, safely below the 165°F limit. As a final test, the environmental conditions of the 1% hot day extreme for ground operations from MIL-STD-210C were applied to the thermal model resulting in a peak adiprene temperature of about 171°F. Although this value is above the defined operational limit, it should be noted that the observed environmental conditions in the Saudi desert during Operation Desert Storm were significantly less severe than those for the MIL STD 1% hot day. Thus, the conclusion is that the missiles stored in Saudi Arabia during Operation Desert Storm <u>did not</u> exceed their maximum operational temperature and they are therefore considered to be safe.

DISCUSSION

A thermal study of the Stinger launch motor was performed to determine if any of the motors exceeded a temperature limit of 165°F during storage in the Saudi Arabian desert during Operation Desert Storm. The procedure was to develop a thermal model of the launch motor inside the launch tube, and to tailor this model using measured data taken in the Kuwaiti desert. The worst-case environmental conditions measured in Saudi Arabia, described in the reference, were then to be applied to the model to obtain predicted motor temperatures.

Stinger missiles were instrumented with thermocouples and placed on the ground (inside the launch tube) in the sun and in a MILVAN near the ceiling during tests in the Kuwaiti desert. Measured temperatures and environmental conditions were recorded, with the results for two separate days reported here: Julian Day (JD) 203 (July 21, 1992) and JD 230 (August 17, 1992). Figure 1 is a photograph of the test station showing the instrumented round, the MILVAN and the apparatus used to measure the environmental conditions. Table 1 gives a brief description of the location of thermocouples in the area of the launch motor on the instrumented round exposed directly to the environment (i.e. not for instrumented rounds that were in the MILVAN or in a container). Figures 2 through 4 show the measured solar radiation, air temperature, and wind speed, respectively, and Figures 5 and 6 show the resulting thermocouple responses for JD 230 and JD 203, respectively (the symbols in the legends of the figures identified with a D or KK refer to data obtained at specific locations in the Saudi desert). For comparison, Figures 2 through 4 also show the MIL STD 210C hot day 1% extreme values. For ease of comparison, the temperature responses of the launch tube (LT), the launch motor (LM) and the ambient air are all shown together in Figure 7. This figure clearly shows how the high wind velocity for JD 230 impacted the measured round temperatures (since the air temperatures were virtually the same for the two days) The temperature response of the launch motor case for the round inside the MILVAN for JD 230 is also shown in Figure 5. Of the days for which temperatures were recorded, JD 230 was the only day for which the launch motor case of the round inside the MILVAN exceeded that of the round lying on the ground in the sun, and this was only by 1°F. This shows that, except for one isolated case, the situation of a round exposed directly to the environment is the worst-case storage condition.

Several limitations of the measured environmental data should be mentioned here. First is the placement of the environmental measurement apparatus which is 15-20 feet above the ground. Conditions measured at this height probably do not adequately represent the conditions to which the round was exposed. For solar radiation, a higher concentration of windblown dust near the surface will attenuate measured solar flux to some extent, especially for the higher wind speeds (such as were measured on JD 230). This effect should be less pronounced for the lower wind speeds measured on JD 203 and for the Saudi conditions. Also, placement of the solar panel caused the solar radiation meter to be shaded for a portion of the day, requiring that the measured solar flux data be extrapolated. An additional extrapolation was required for the Saudi solar radiation data which abruptly dropped to about 10% of its expected value for two to three hours in the middle of the day (possibly caused by shadowing or misreading of the instruments).

The wind speed at ground level would almost certainly be different than that measured 15 to 20 feet above the ground, but in the Kuwaiti cases the wind speed and direction near the launch tube were even more poorly known due to the fact that the wind, which was predominantly out of the north for the two days reported here, had to flow around the MILVAN before it reached the instrumented round (the round is located approximately due south of the MILVAN, based on the assumption that the solar panel is directed to the south). Thus, the wind speed could have been almost any value between zero and the measured value, and could have been from any direction. Supporting this assertion were reports that wind blown sand was cleared away from the side of the round at the end of the day.

Ambient air temperature is another parameter which is affected by the placement of the measuring device. The air temperature at 15 to 20 feet above the ground can be significantly different than the air temperature within a few inches of the ground, where the instrumented missiles were located, due to convection heat transfer from the hot ground to the air.

A sketch of the thermal model used in the study is shown in Figure 8, along with dimensional and thermal property data. The model consists of a full cross-section of the launch motor encompassing two axial locations; through the adiprene potting material and through a section immediately aft of this section containing the propellant sticks (node numbers without parentheses represent the forward axial position and node numbers within parentheses represent the aft axial position). The forward and aft closures were not included in the model. The cross-section was divided into six sectors, as shown in the figure, with the top five sectors being 1.0 radian in angular size, and the bottom sector being 1.283 radians. The round orientation in the tests was north-south, thus in the thermal model the sun was assumed to rise on one side of the model and set on the other. The measured solar insolation data was applied to the top side of the model unmodified (except for the extrapolations mentioned above), since this surface is virtually horizontal. The solar insolation data was modified for the four upper sectors of the model (above ground level) based on a simple cosine law. For the upper, sunrise side of the model, the applied solar heat flux was assumed to be the measured value until the sun reached an angular position equal to the angular position of the center of the sector. Thereafter the applied heat flux was reduced to the measured value times the cosine of the angle between the sun's angular location and the angular position of the center of the sector (the angle β in Figure 8), for angles less than 90°. For angles greater than 90°, while the sun was still in the sky, the applied heat flux was assumed to be a value of 10 BTU/hr-ft^2-sec, to account for diffuse solar radiation. (This simple cosine rule was also applied to the lower sunrise and sunset sectors.) A similar method was used on the upper, sunset side of the round, but with the diffuse value of 10 BTU/hr-ft^2-sec being applied during the morning hours and the actual measured value being applied only after the angular position of the sun was below the angular position of the center of the sector. Use of this method is recognized as a first approximation. A more elaborate determination of the variation of the solar flux around the launch tube could be developed if a more refined model is desired. A solar absorptivity of 0.8 was assumed for the launch tube, with no directional variability.

The five sectors receiving solar heat inputs in the thermal model were also assumed to exchange heat with the surroundings through convection and radiation. These surfaces were assumed to exchange energy with the sky with an emissivity (or absorptivity when the sun was down) equal to 0.8, and with a sky temperature equal to the air temperature minus 20°F (i.e. $T_{SKY} = T_{AIR}$ - 20°F). The lower two sectors were also assumed to exchange heat with the ground by radiation. Reflection of solar energy from the surroundings to the launch tube was ignored in the analysis. The bottom sector of the launch tube was assumed to exchange heat with the ground through conduction. As mentioned above, determination of the heat transfer coefficient on the surface of the launch tube due to the wind would be difficult to determine analytically because the wind speed and direction are unknown. Therefore, a trial-and-error method was used to determine this value. A peak value of the heat transfer coefficient was first assumed. This value was substituted into the equation

$$h = C\sqrt{V}$$

where h is the heat transfer coefficient, C is a constant and V is the wind velocity in ft/sec, to determine the value of C. This equation was then used (with the calculated value of C) with the measured wind velocity history to determine heat transfer coefficients for different times during the day (the wind speeds shown in Figure 4 were smoothed for entry into the thermal model, as shown in that figure). The thermal model was then run and the predicted launch tube temperature response was compared with the measured response. The peak heat transfer coefficient was then adjusted and the process repeated until a satisfactory match was obtained. A minimum value of the heat transfer coefficient of 1 BTU/hr-ft^2-sec was used to account for natural convection effects.

Heat conducted through the launch tube was allowed to conduct and radiate across the air gap to the launch motor case. An absorptivity of 0.3 was assumed for the launch motor case. Heat was then allowed to conduct into the adiprene or the propellant. For simplicity, the propellant sticks were modeled as a solid substance, but with a reduced density to account for the air inside and around each propellant stick. The thermal conductivity in the radial and circumferential directions of the propellant was also reduced to account for air conduction between the propellant sticks. (The reduced density and thermal conductivity values are listed in Figure 8 with an asterisk to make it clear that these are not the actual property values.)

All thermal simulations were started at a clock time of 0500 using extrapolated air temperature and wind velocity data, since measured data were not available. This was necessary to determine the temperature distribution prior to the onset of recorded measurements, since no soak temperature was reported. Figure 9 shows how the predicted launch tube and launch motor temperature responses compared with the measured data shown in Figure 5 (JD 230). For times prior to solar noon, the predictions lag the measurements somewhat, but then the predicted peak value of the launch motor case of 131°F exceeds the measured value of 129°F. The measured and predicted launch tube temperature peaks are about the same. After solar noon, the measured launch motor case temperatures appear to "bulge" out above the predicted response. It is not clear why this bulge exists in the launch motor case temperatures and not in the launch tube temperature response. Further analysis would be required to more clearly determine why this discrepancy occurred. Although this may be of some academic interest, it is not germane to determining the peak temperature values.

Figure 10 shows the analogous comparison for JD 203 (ref. Figure 6). Ignoring the very first data point, the predicted launch tube temperatures generally closely match the measured values. The predicted launch motor case temperatures lead the measured values slightly, and, as with the JD 230 data, the peak predicted valuo of almost 149°F exceeds the measured value of 147°F. The predicted launch motor temperatures in both cases slightly exceed the measured values, thus, the predictive model is somewhat conservative. This conservatism may be caused by the absence of the forward closure in the thermal model, which represents a relatively large thermal mass. If desired, this model can be expanded to include the forward closure at a later date.

The thermal model used for JD 203 was then used to predict launch motor case temperatures for conditions measured in the Saudi desert during Desert Storm (since the wind velocities for the Saudi days were also low). The environmental conditions for KK 7/12/91 (see Figures 2 through 4) were chosen as a worst-case. The results for this case are shown in Figure 11. Not surprisingly, the increased solar flux (see Figure 2) and air temperature (see Figure 3) in the Saudi case resulted in increased round temperatures, with the launch tube achieving a temperature of about 174°F (vs. 164°F for JD 203). The predicted peak launch motor temperature, at the adiprene axial location, attained a value of 153°F for KK 7/12/91 vs. 149°F for JD 203. These results imply that storage in the Saudi desert during Operation Desert Storm did not result in excessive temperatures for the Stinger launch motors. It should be noted that these results are based on a thermal model tailored to the Stinger round being oriented in a very specific way in relation to the sun and the wind. It is unlikely that the missiles stored in Saudi Arabia during Operation Desert Storm had this same orientation (i.e. some other orientation, such as an east-west aligned round, may represent a more severe heating condition). To determine the magnitude of the effect of orientation, a case was run with an east-west oriented round with the results showing no significant effect on peak motor temperatures.

One final case evaluated was to expose the thermal model to the environmental conditions of the 1% hot day extreme for ground operations from MIL STD 210C (again, see Figures 2 through 4). These predicted temperature results are shown in Figure 12. The launch tube in this case attained a temperature of 195 °F, and the resulting temperature of the launch motor case at the adiprene axial location was 171°F. Although this value is 6°F above the specified limit of 165°F, it is not clear that this represents a problem. First, the thermal model over-predicted rocket motor case temperatures for the two correlation conditions, and second, the upper limit of 165°F may not be a firm number. Regardless, it is emphasized that none of the observed conditions in Saudi Arabia and Kuwait were as severe as those of MIL STD 210C.

Thus, the slightly excessive temperature predicted for the MIL STD 210C conditions has no bearing on the question of whether the actual missile rounds experienced excessive temperatures.

CONCLUSIONS

A thermal model of the Stinger launch motor inside the launch tube was developed for the ultimate purpose of predicting the peak temperature attained of the adiprene potting material inside motors stored in Saudi Arabia during Operation Desert Storm. The concern was that the adiprene may have exceeded its maximum operational temperature limit of 165°F (defined by the motor manufacturer Atlantic Research Corporation), which, if true, could potentially result in launch motor case overpressure upon use. The thermal model was tailored using measured motor temperatures and environmental conditions collected on two days in the summer of 1992 (Julian Days 203 and 230) at a station in the Kuwaiti desert. It should be recognized that the sophistication level of the model resulted in some discrepancies between predicted and measured data that cannot be fully explained. However, use of the measured data to tailor the thermal model, coupled with the similar conditions in the Saudi and Kuwaiti environments and the slight conservatism of the model, lends confidence to the predicted peak temperatures. Further refinement of the thermal model can be performed at a later date, if desired.

Following tailoring of the thermal model, the worst-case conditions recorded in the Saudi desert were applied to the model, with the results being that the adiprene attained a peak temperature of only 153°F, well below the specified limit of 165°F. This establishes that the hardware in question (i.e. those rounds stored or used) in the Desert Storm activity are <u>not</u> considered to be unsafe.

A final analysis using the environmental conditions of the MIL STD 210C, 1% hot day extreme for worldwide operations was also performed. These conditions resulted in a peak adiprene temperature of 171°F, 6°F above the specified limit. This implies, for the overall design (not the Desert Storm or Kuwait hardware), that using worst-case conditions could possibly result in slightly excessive adiprene temperatures. Additional analyses and tests would be required if it was intended that Stinger missiles would be stored under these conditions, and if the 165°F limit is a firm number. It must be pointed out that none of the conditions recorded in Saudi Arabia during the time of storage of the missiles were as severe as those for MIL STD 210C, and thus, none of the stored rounds are expected to have attained an unsafe temperature.

TABLE 1

Launch Motor[1] Thermocouple Locations on Exposed, Instrumented Round

Thermocouple Number	Thermocouple Location
16	0.010" in 1 o'clock position of 12 o'clock stick on outside row
17	0.010" in 12 o'clock position of 12:03 o'clock stick on second row
15	O.D. of Launch Motor case over #16
30	O.D. of Launch Tube over #15
31	O.D. of Launch Tube 180° from #30 (no data was available from this thermocouple)

1. Locations of thermocouples at other positions on the instrumented rounds and for other rounds are not described here since they do not pertain to this analysis.

Figure 2 Comparison of Solar Radiation Data

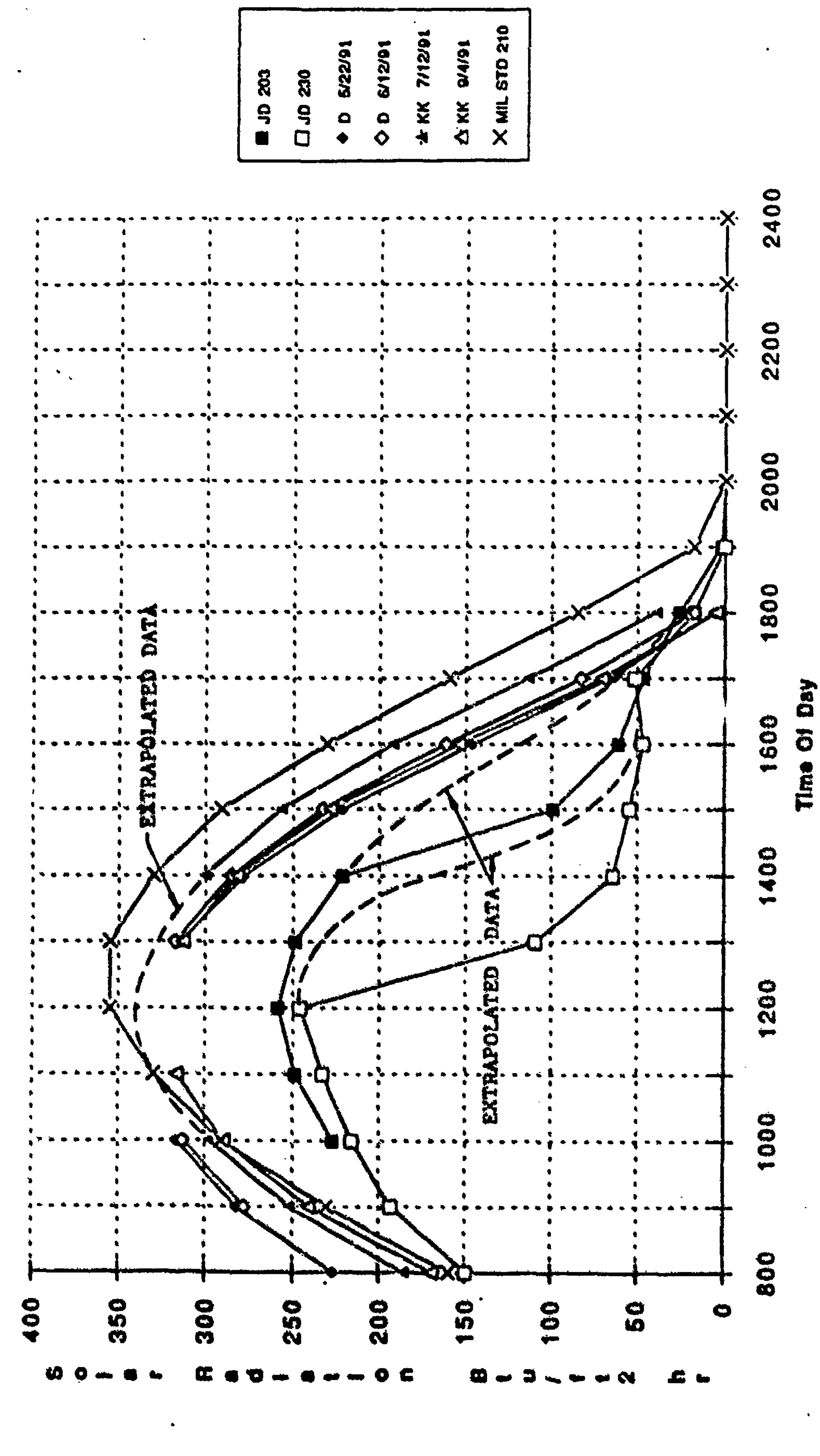


Figure 3 Comparison of Ambient Air Temperatures

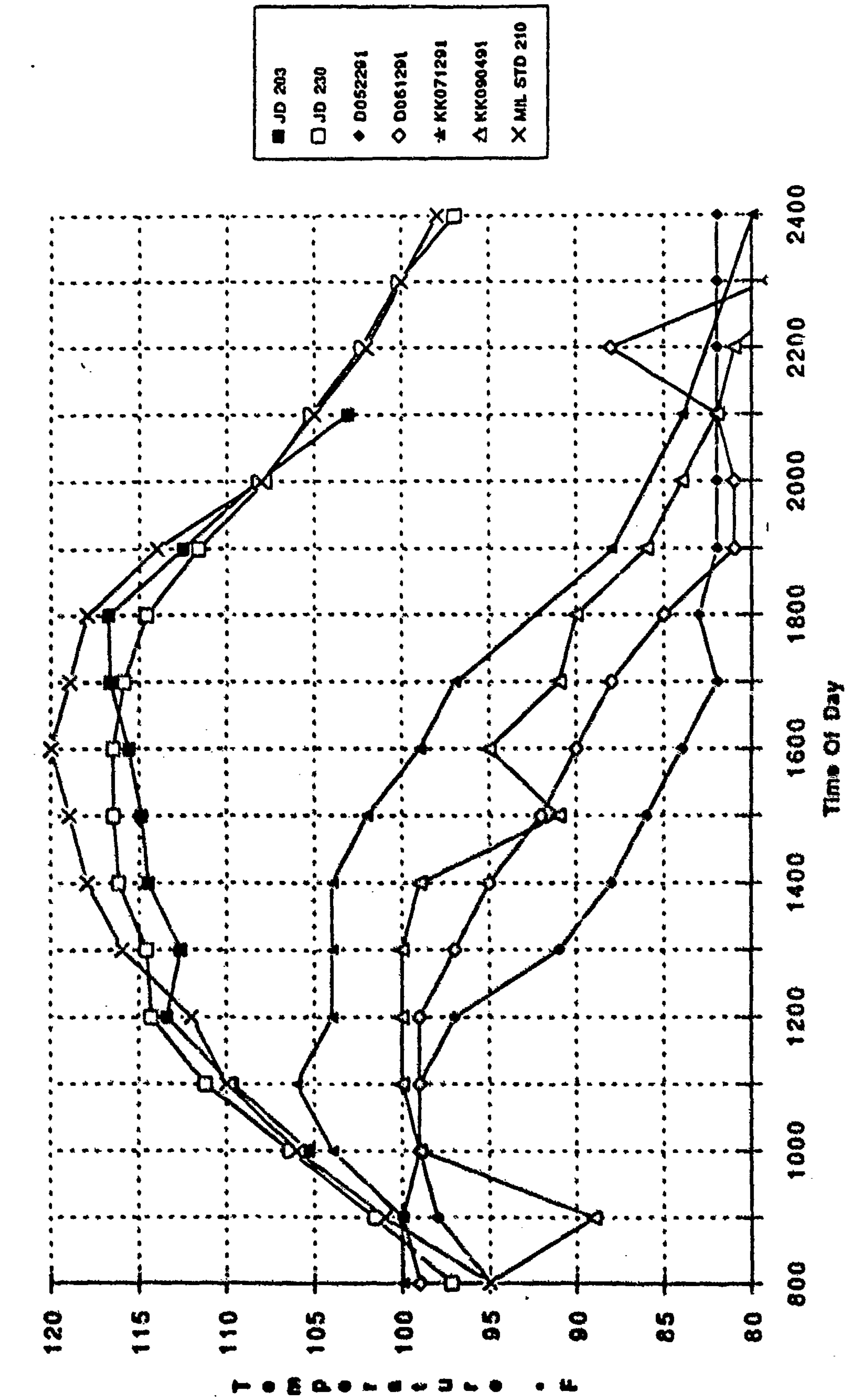
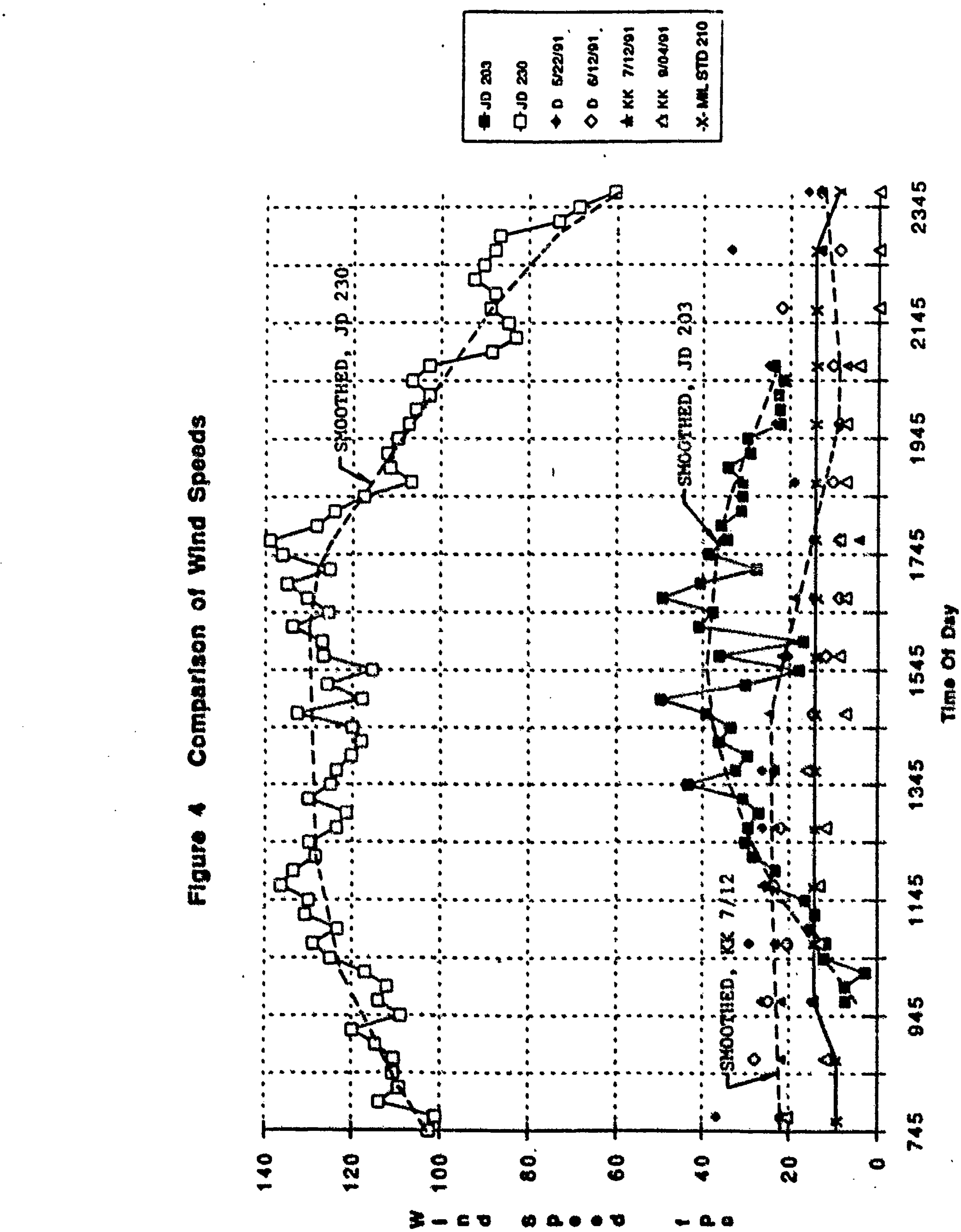


Figure 4 Comparison of Wind Speeds



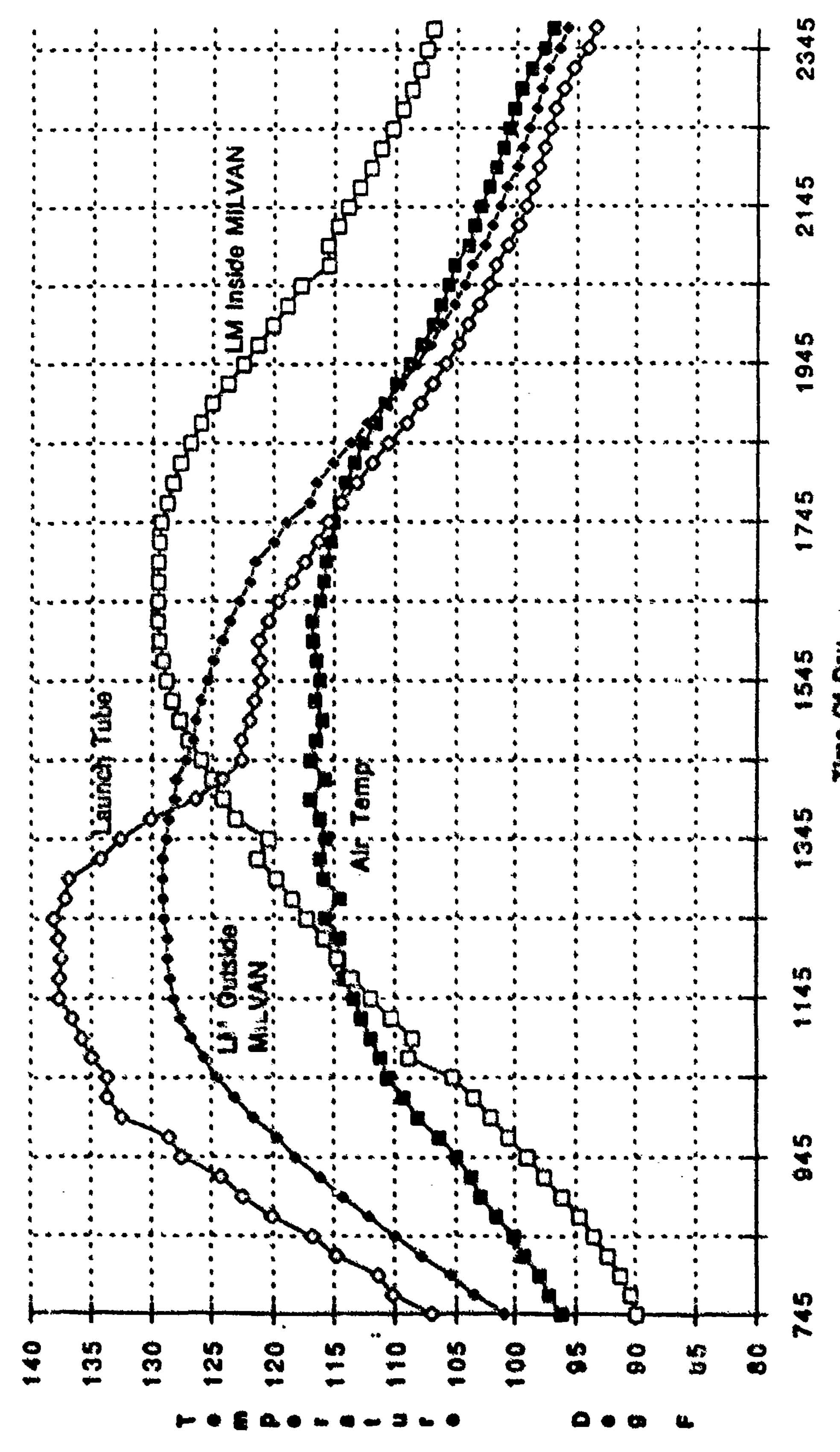
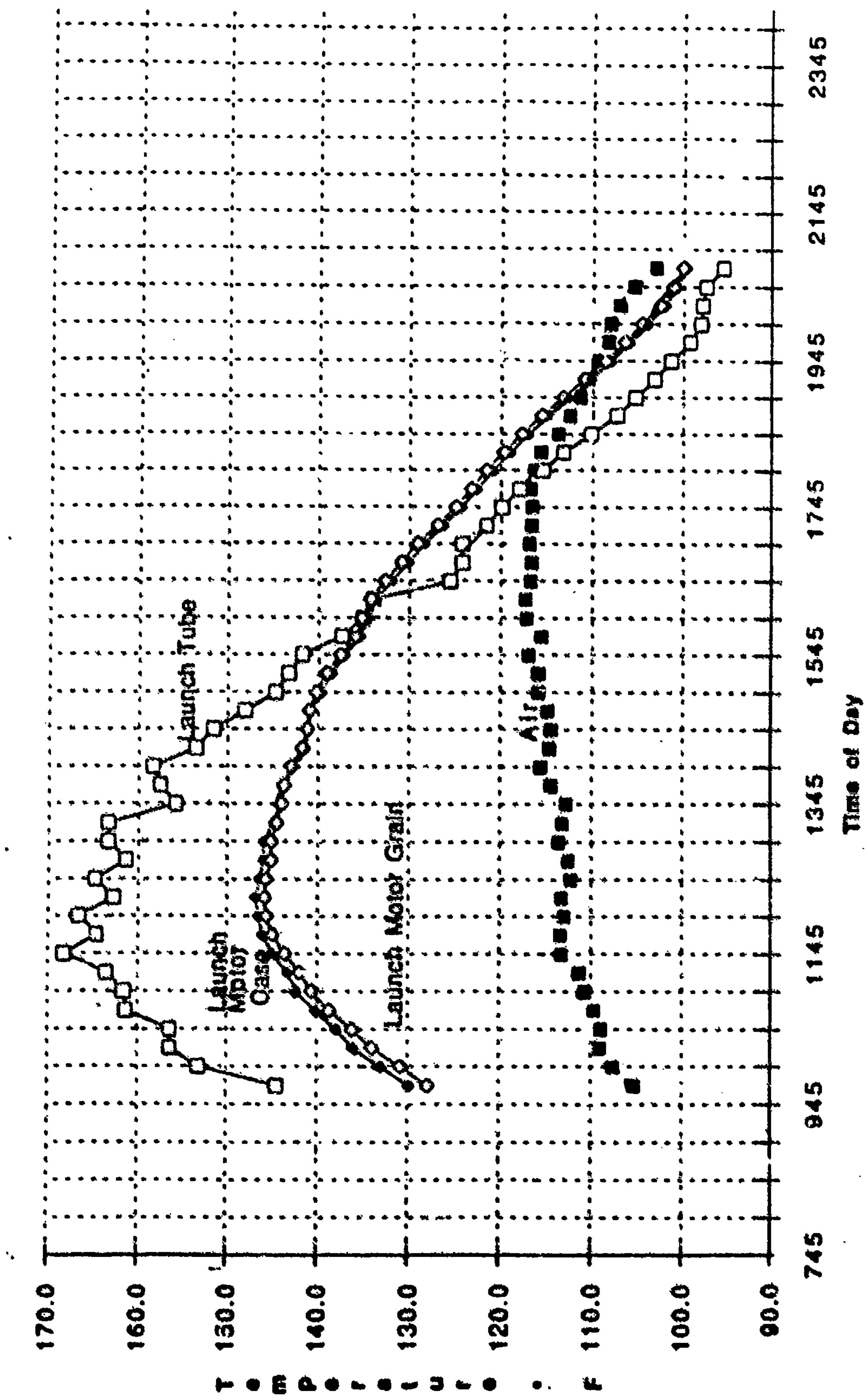


Figure 5 Measured Temperature Data for Kuwait JD 230

Figure 6 Measured Temperature Data for Kuwait JD 203



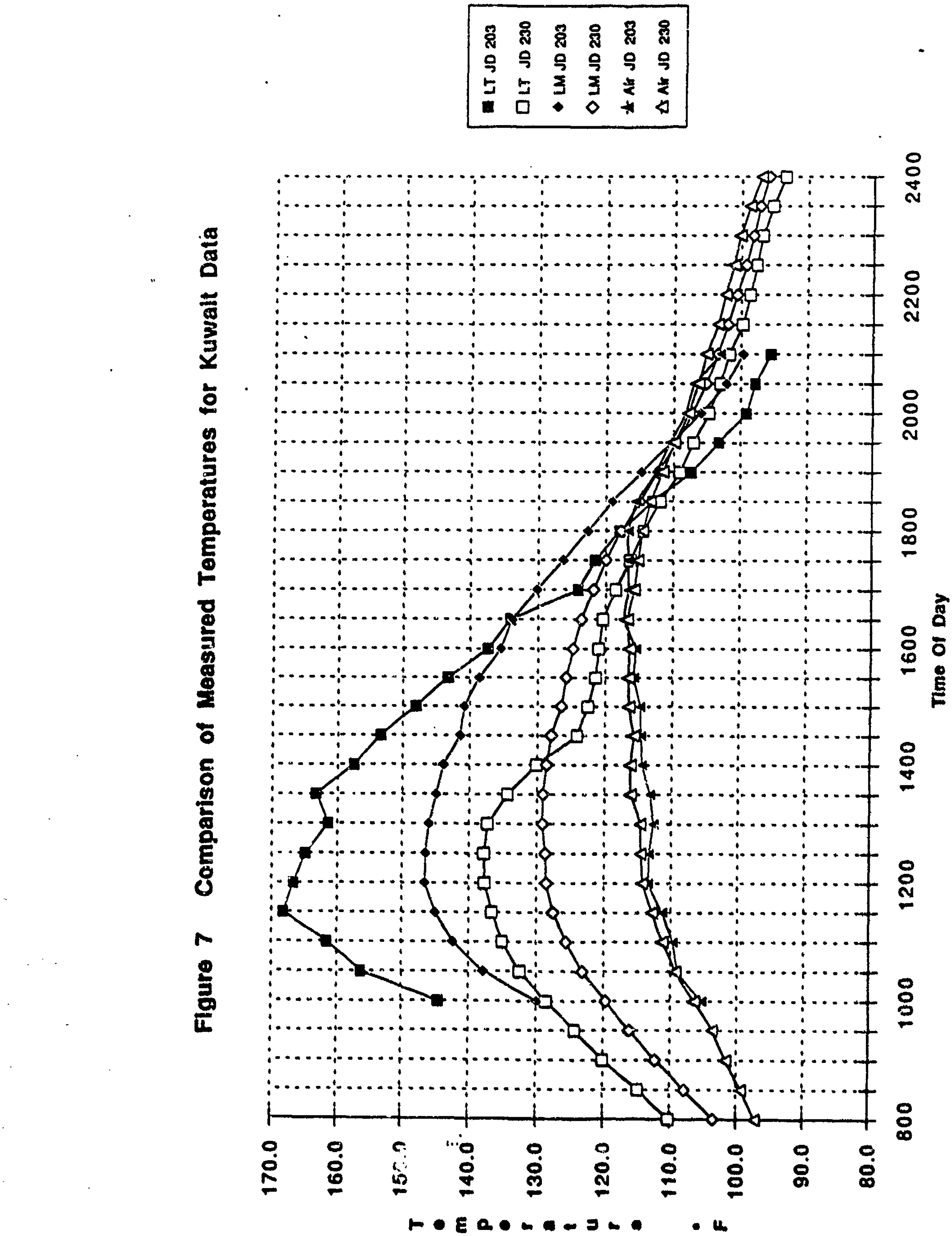
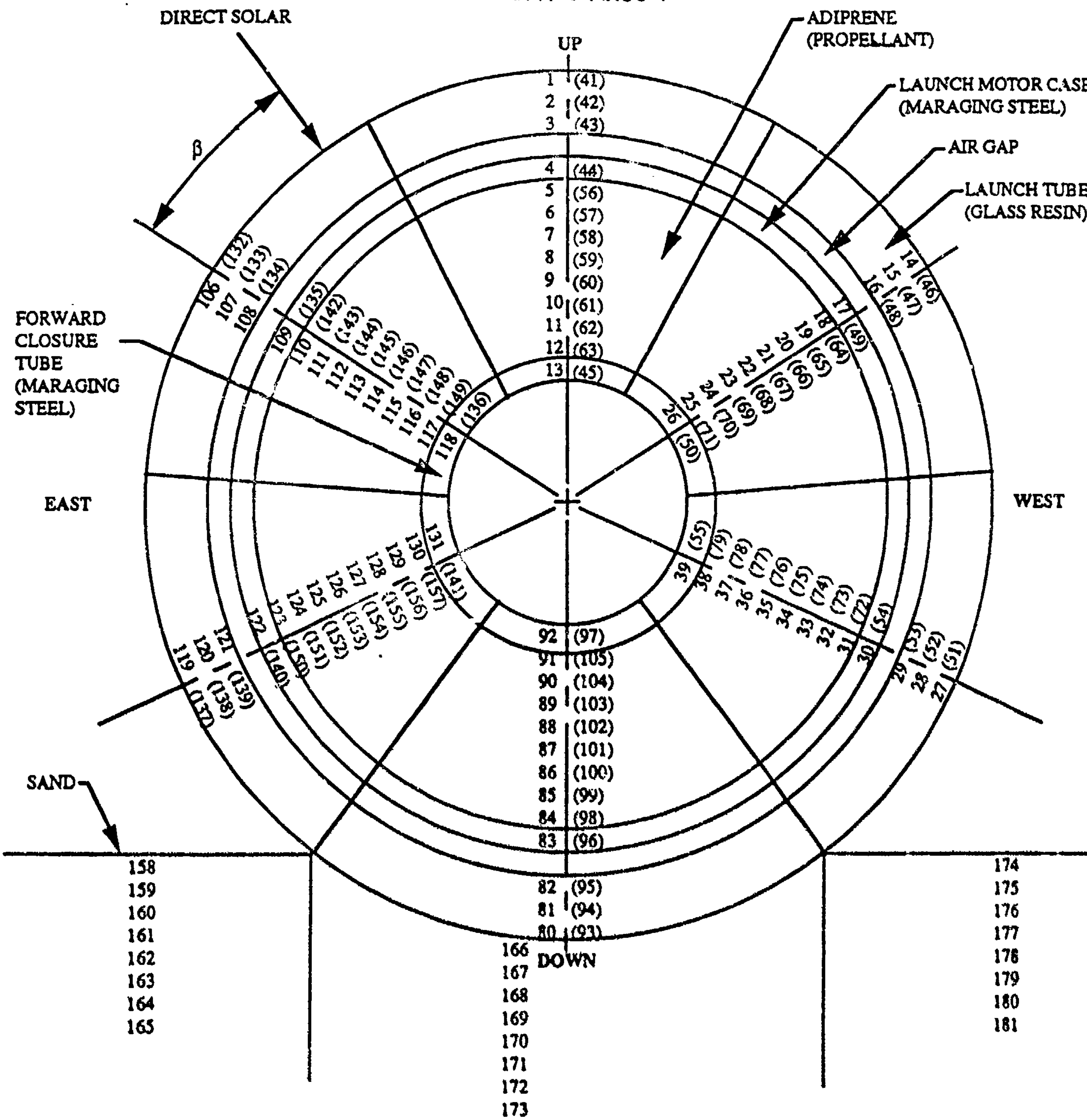


Figure 7 Comparison of Measured Temperatures for Kuwait Data



DIMENSIONAL/PROPERTY DATA:

COMPONENT	OUTER RAD.	INNER RAD.	DENSITY	SPECIFIC HEAT	THERMAL CONDUCTIVITY
LAUNCH TUBE	1.425 in.	1.355 in.	112.3 lb/cu.ft	0.21 BTU/lb-°F	0.175 BTU/hr-ft-°F
LAUNCH MOTOR CASE	1.322	1.258	494.2	0.12	12.2
ADIPRENE	1.258	0.480	104.1	0.25	0.22
(PROPELLANT)	1.258	0.480	69.0*	0.26	0.22 /0.04*
FORWARD CLOSURE TUBE	0.480	0.400	494.2	0.12	12.2
SAND	-	-	94.6	0.19	0.156

FIGURE 8. Schematic of Motor Thermal Model Showing Node Locations (Not to Scale)

Figure 9 Comparison of Predicted and Measured Temperatures for JD 230

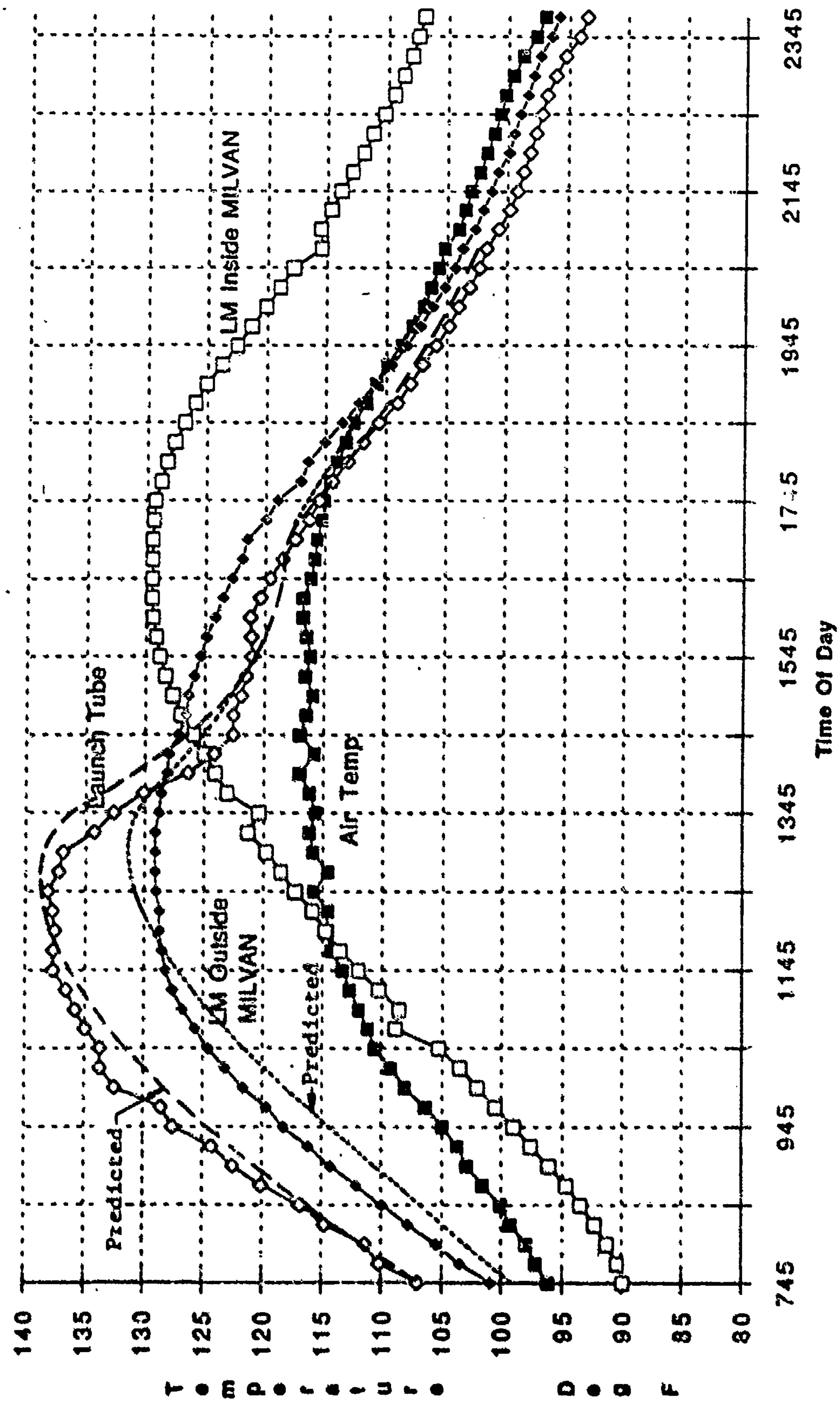
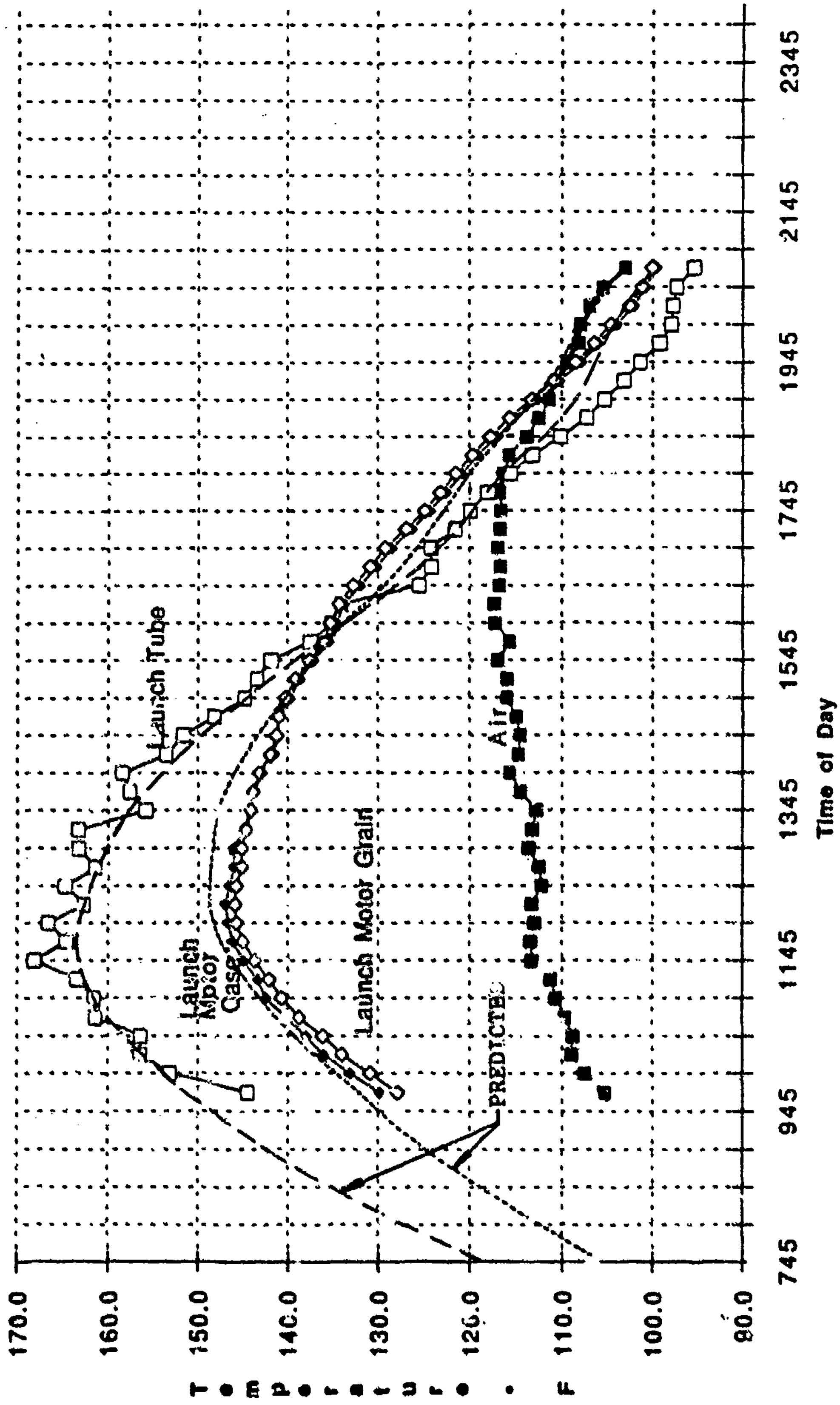


Figure 10 Comparison of Predicted and Measured Temperatures for JD 203



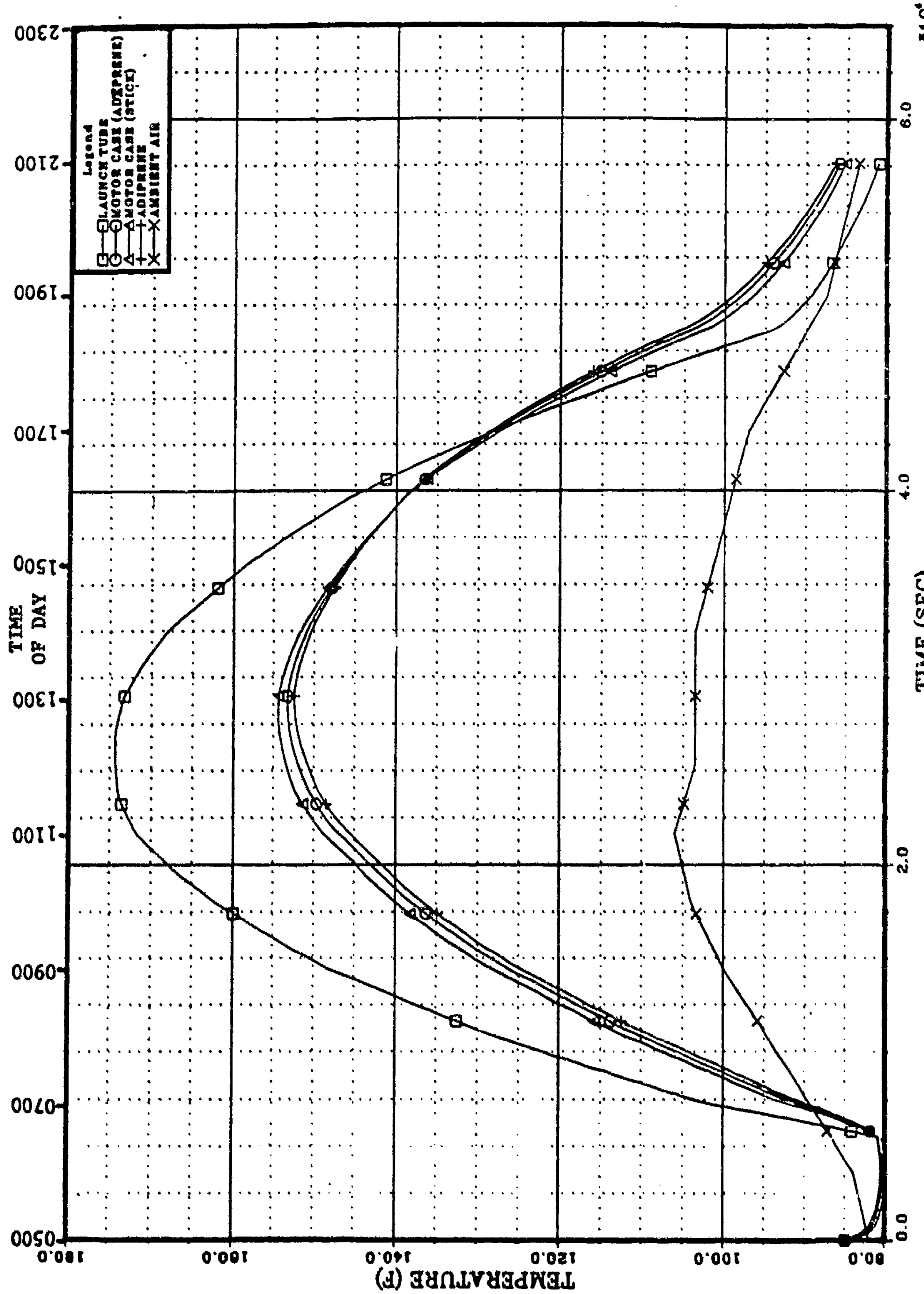


Figure 11 Predicted Launch Tube and Launch Motor Temperatures for KK 7/12

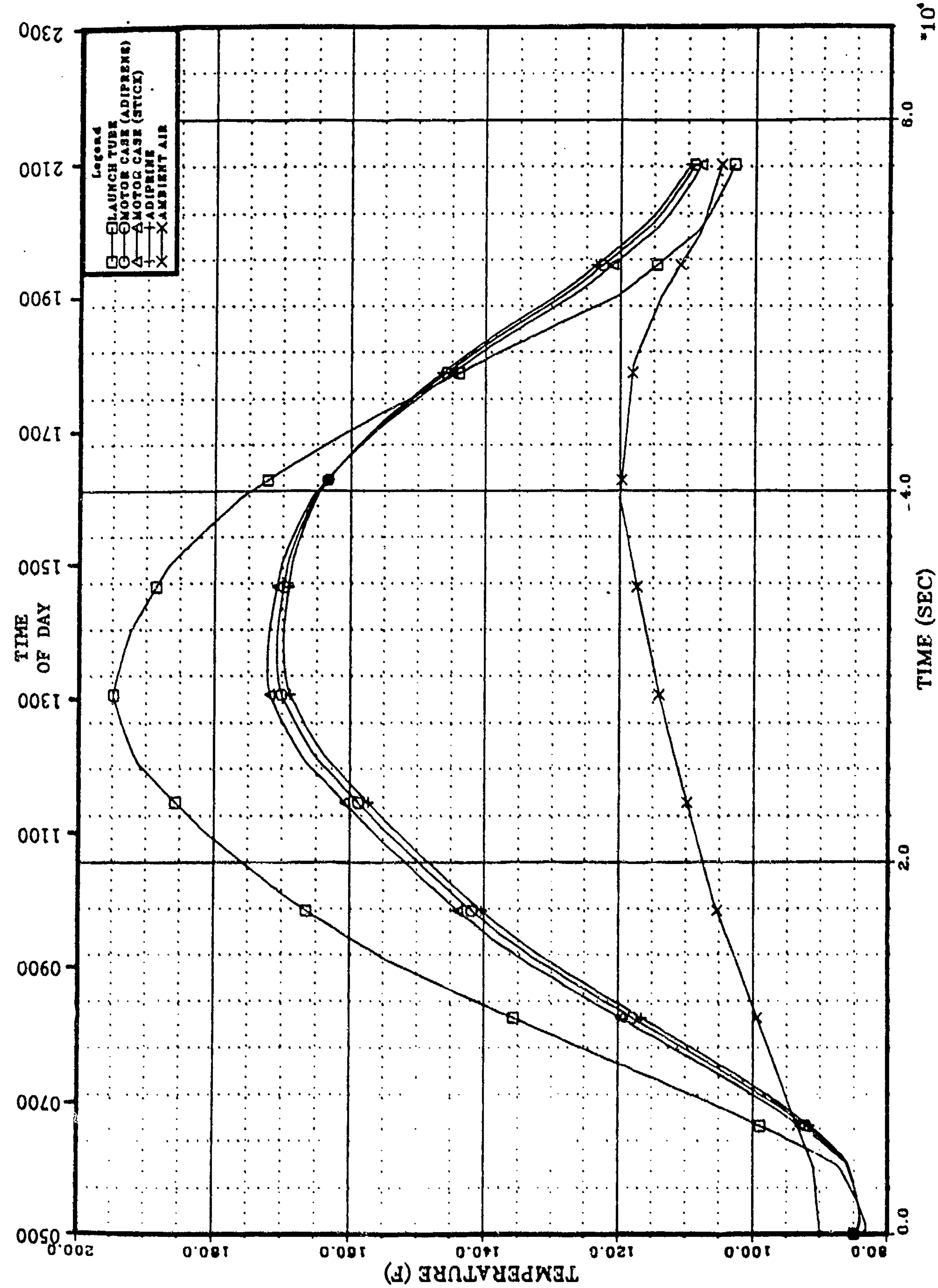


Figure 12 Predicted Launch Tube and Launch Motor Temperatures for MIL STD 210